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An Analysis of User Cost and Service Trade-Offs in Transit and Paratransit Services

Cambridge Systematics, Inc., MA

Prepared for

Transportation Systems Center
Cambridge, MA

Aug 79

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An Analysis of User Cost and Service Trade-Offs in Transit and Paratransit Services

Final Report
August 1979

Service and Methods Demonstration Program

U.S. DEPARTMENT OF TRANSPORTATION
Urban Mass Transportation Administration
Research and Special Programs Administration
Transportation Systems Center

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16. Abstract

The Xenia Model Transit Service served as a test of several alternative transit services operated in a small city setting. This project was undertaken as an aid to the evaluation of transit and paratransit systems in Xenia, Ohio, and as a test of a new technique for assessing travel demand. The technique, direct utility assessment, was designed to test a new method for assessing user trade-offs in costs and service based on attitudinal methods. A tradeoff survey was administered as part of a home interview survey. Data from the tradeoff survey were used to develop separate equations for each sample respondent to explain and describe their tradeoffs over transit fare, travel time, walk distance, type of service, and headway. An aggregate equation was also developed, assuming that all respondents shared common tradeoffs.

These equations were employed to retrospectively predict changes in transit system patronage (since 1974). Both sets of models performed well, producing forecasts that were in the same direction and range of experience, although magnitudes were somewhat different. Coefficients of the individual tradeoff equations were then analyzed to see if they could be predicted on the basis of interpersonal characteristics of the respondents. Results indicated that differences in coefficients could be attributed to some differences in individuals such as income and auto ownership. Overall results were promising for policy evaluation and forecasting. This report contains a bibliography.

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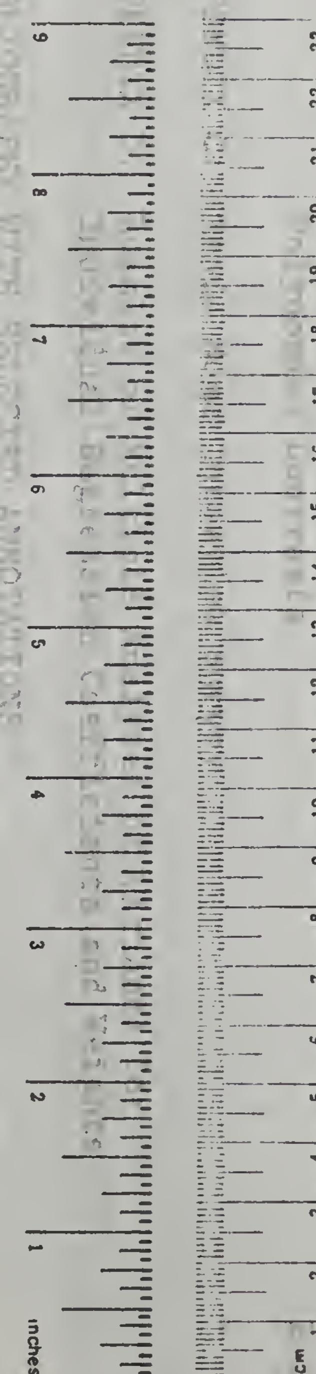
METRIC CONVERSION FACTORS



Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
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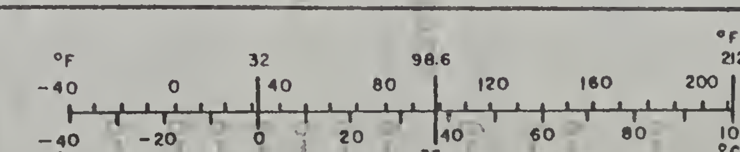

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

As part of the Urban Mass Transportation Administration Service and Methods Demonstration (SMD) Program, Cambridge Systematics, Inc., under contract to the US Department of Transportation, Transportation Systems Center, has prepared the following final report on An Analysis of User Cost and Service Tradeoffs in Transit and Paratransit Systems.

This report is based on analyses of data collected with the assistance of the Xenia Department of Transportation, the Transportation Coordinating Committee and the Montgomery - Greene County Transportation and Development Program. Carla Heaton of the Transportation Systems Center was the Project Monitor for this study and provided guidance for the effort.

The authors would also like to thank the Cambridge Systematics, Inc. staff who assisted on the project. Melissa Laube assisted in the writing of Chapters 2 and 3; James Wojno assisted in data preparation and graphics. Several University of Iowa faculty provided valuable advice and assistance with data analysis: George Woodworth in Statistics, Jerry Eskin in Marketing, and Jim Stoner in Civil Engineering.

very difficult. This situation arose because the fixed-route transit system in Xenia operated at uniform headways, fares, and routes on all routes; and auto travel time was characterized by relatively uniform speeds and no parking costs. The paratransit system had only system-level data on average wait times and travel times, and very limited variation in fares. In all cases, there was insufficient variation in most variables of interest to adequately assess their impact on travel choice. Thus, the evaluation was extremely limited in its ability to address the user and service level tradeoffs between transit and paratransit systems, a key objective of the evaluation. The direct assessment technique was introduced in response to this need.

The lack of variability in the explanatory level-of-service variables found in Xenia is likely to be encountered in many small urban areas with simple transit and highway networks. Thus, this methodology, if successful, can have applications in many other demonstration projects. Other cases in which direct utility assessment offers the promise of improved analysis capabilities are the introduction of new modes (often done in SMD projects), the effect of new settings on travel behavior (for example, gas rationing, on which no data currently exists), or for variables affecting travel demand which are unmeasurable, important or too expensive to measure (for example, the effect of small versus large buses in a service in which only one vehicle type has been used). All of these areas may be of interest in future projects.

1. EXECUTIVE SUMMARY

1.1 Methodology

This project was undertaken as an aid to the evaluation of transit and paratransit system in the Xenia, Ohio Service and Methods Demonstration (SMD) project, and as a test of a new technique for assessing travel demand. The technique is called direct utility assessment, and consists of an experimental design (described below) containing a set of situations in which individuals are asked to rate their likelihood of making a certain choice, in this case of using transit versus driving. These responses can then be analyzed to produce a utility function with respect to the variables contained in the situations, for each individual or for groups of individuals. The utilities can then be related to the actual decision-making of the sample.

The heart of the technique is the experimental design. In it, a set of variables are defined, each with several discrete levels, in such a way that each variable is completely uncorrelated with every other variable. This independent, or orthogonal, design allows one to analyze the response to each variable totally unconfounded with any other variable. This propensity of the direct utility assessment technique is what motivated its use on the data from Xenia, as the actual data describing travel choices in Xenia was very highly correlated, and made the calibration of a more typical demand model

very difficult. This situation arose because the fixed-route transit system in Xenia operated at uniform headways, fares, and speeds on all routes, and auto travel also was characterized by relatively uniform speeds and no parking costs. The paratransit system had only system-level data on average wait times and travel times, and very limited variation in fares. In all cases, there was insufficient variation in most variables of interest to adequately assess their impact on travel choice. Thus, the evaluation was extremely limited in its ability to address the cost and service level tradeoffs between transit and paratransit systems, a key objective of the evaluation. The direct assessment technique was introduced in response to this need.

The lack of variability in the explanatory level-of-service variables found in Xenia is likely to be encountered in many small urban areas with simple transit and highway networks. Thus, this methodology, if successful, can have applications in many other demonstration projects. Other cases in which direct utility assessment offers the promise of improved analysis capabilities are the introduction of new modes (often done in SMD projects), the effect of new settings on travel behavior (for example, gas rationing, on which no data currently exists), or for variables affecting travel demand which are unmeasurably invariant or too expensive to measure (for example, the effect of taxis versus buses in a service in which only one vehicle type has been used). All of these areas may be of interest in future projects.

The analysis of user cost and service tradeoffs in transit and paratransit systems in Xenia, Ohio involved four major components which were designed to assess user tradeoffs among cost and level-of-service attributes through the application of direct utility assessments. These research components were:

1. To develop a survey instrument which could be used to measure respondent tradeoffs among the attributes of cost, type of transit service, headway, walk distance, and travel time differences of transit compared to auto. This instrument was developed for use with the Xenia, Ohio Home Interview Survey conducted as part of the evaluation of a model transit service demonstration program in operation in Xenia since 1974. The instrument consisted of 18 different hypothetical transit systems, each with a different combination of levels of the four attributes.[1] For example, one alternative was a fixed-route bus system which passed by a bus stop six blocks from the respondent's residence on a 15-minute headway, charged a 50-cent fare and took the same amount of time to reach the respondent's destination as an automobile; a second alternative was a paratransit (taxi) system that could be called on demand, charged a 50-cent fare and took 20 minutes longer to reach the respondent's destination than a private automobile. The respondent was asked to estimate, by responding on a numerical scale to each alternative, "how frequently

[1] Headway and type of transit service were considered a single composite attribute; cost, walk time, and travel time were the others.

he or she might use" each of these two services and an additional 16 alternatives to make a typical work or shopping trip. In addition to these data, each respondent supplied current and historical personal data about themselves and their household.

2. Because there are 18 numerical response observations for each individual from the survey, it was possible to develop unique regression equations for each respondent to explain and describe their tradeoffs. The equations are of the following general form:

$$L_i^j = \beta_0 + \beta_1(TS_i) + \beta_2(BH_i) + \beta_3(TH_i) + \beta_4(F_i) + \beta_5(F_i^2) + \beta_6(W_i) + \beta_7(W_i^2) + \beta_8(T_i) + \beta_9(T_i^2) + \varepsilon_i, \qquad (1.0)$$

where L_i^j is the predicted numerical response to each of the i (=18) alternatives for trip purpose j (work or shop)

TS_i is the type of transit system (bus or paratransit)

BH_i is the headway for fixed-route bus (every 15 or every 30 minutes)

TH_i is the "headway" for paratransit (taxi) system (call two hours ahead or on demand)

F_i is the fare charged (free, 50 cents, \$1); F_i^2 is fare level squared, used to detect nonlinearity in the response to fare

W_i is the number of blocks to walk to the nearest transit stop (0, 3 or 6 blocks); W_i^2 is the square of this walking distance

T_i is the difference in travel time between auto and transit; T_i^2 is the square of travel time (transit 0, 10 or 20 minutes longer than auto)

$\beta_0 - \beta_9$ are regression coefficients

ε_i is the error term

Note that the presence of squared terms allows one to test for non-linear and threshold effects in individuals' responses. Out of 670 respondents surveyed, 451 supplied sufficient data to estimate a unique equation.

3. Once the individual equations were estimated, the third research task involved testing whether the personal and household measures obtained during the home interview could account for (explain) differences in the individual coefficients; for example, as household income rises, one might hypothesize that individual coefficients for cost might become less negative and/or cost might have less impact or explain less variance relative to other factors such as time. A number of similar hypotheses regarding interpersonal measures were tested by means of a multiple analysis of variance in which the individual regression coefficients are dependent variables and the interpersonal measures are explanatory variables. Results indicate that there are a number of highly significant relationships between individual coefficients and interpersonal measures. These results can be used to assess differences in the responses of different traveller groups to proposed level-of-service and cost changes. Hence, this type of analysis can guide design and implementation of demonstration projects as well as evaluate the impacts and results of such projects.

4. The next task was to develop forecasting systems that could be used to retrospectively predict the transit mode shares back through time for each of the major stages in the demonstration in

order to provide a preliminary assessment of validity and usefulness. There were a number of significant changes in fares and levels of service between 1974 and the present in Xenia beginning with free fixed-route bus service with a 30-minute headway in 1974. There were two route structure changes and one fare increase to 25 cents in 1975; then the system was converted to a paratransit mode with a 50-cent fare for call-ahead or immediate request service in 1976, followed by a fare differentiation in 1977 of 50 cents for off-peak call-ahead, 75 cents for peak call-ahead and $1 for peak immediate request service.

In order to forecast the transit mode shares for these systems, two modelling approaches were developed. First, a "totally individual" system using all 451 regression equations described above was created. Values for the four attributes were measured for each individual intra-Xenia trip observed in the travel survey portion of the home interview survey for each of the five system changes of interest since 1974. These attribute measures for each trip (type of mode, headway, cost, walking distance and travel time difference) were substituted in the equation of the respondent who made the particular trip to generate predicted "likelihood to use" values for each mode alternative. To predict choice it was assumed that the respondent would be most likely to select that mode alternative (auto or the transit system available at the time) which his or her equation predicted them to be <u>most</u> "likely to use"; i.e., the <u>highest</u> predicted

value. Mode shares were generated by counting the total number of respondents who were "most likely" to choose each alternative mode.

Results of this exercise were reasonably consistent with the pattern of ups and downs in the observed Xenia patronage, particularly for work trips. Also, the magnitude of the estimates was within the range of experience in Xenia, although too low in 1974 and too high in 1977. Reasons for discrepancies cannot be discerned from the data but may be due to replacement of autos damaged in the 1974 tornado, influences of variables such as reliability which were not included in the model, or error in the measurement of the attribute values. Nonetheless, a strong rank-order relationship exists between observed experience and mode forecasts at an aggregate level.

A second alternative analysis approach was developed that focused on the proportion of "regular" users of any of the systems. The proportion of responses which indicated a greater than 50 percent "likelihood of use" was calculated for each of the 18 alternatives. These proportions were used as the dependent observations and Equation 1.0 was fit to these data using regression analysis. This is an ad hoc approach based on the observation from previous applications of the technique that respondents may overstate their intent to use transit. By using only responses of seven or more on an 11-point scale (greater than 50 percent likelihood of transit use), this bias is partially compensated for. If this second model were to fit the data significantly better than the first, it would be indicative of this bias. More formal techniques should be developed to deal with it, however.

The average system-wide values of the four attributes were calculated for each of the five system changes of interest from 1974-1977. (This is a reasonable approximation for reasons mentioned earlier; namely, the lack of variation in level-of-service measures.) These average values were substituted into the equation described above to predict the proportion of "regular" users for each system.

Results again were in the same rank order as experienced in Xenia, and the magnitudes of proportions were also within the range of observation. Once more, 1974 estimates were too high and 1977 too low. Elasticity values for the fare changes were calculated from the equation for "regular" users, and these values were compared with values observed in Xenia during the demonstration. Again, the rank order was correct, but the magnitudes were not. However, the consistency of the rank-order relationships suggests the possibility that a simple transformation can be found that would permit one to derive the "correct" estimates from the survey data. Also, there is some indication that bus and taxi values are different, but there is insufficient data to draw a stronger conclusion.

5. The final task was to develop a traditional logit choice model for the Xenia data and compare the results. This could not be completed because there was insufficient variation in the attribute data in 1977 to permit model estimation.

Conclusions are that results provide positive support for continued research into the application of this approach to assessing service and

cost tradeoffs and more general travel demand issues. Results show that the approach can be implemented easily and that it has the potential to generate data useful for policy formulation and evaluation.

1.2 Conclusions on User Service and Cost Tradeoffs

The results of the research permit a number of conclusions about user cost and service tradeoffs by type of user.

1. Consistent with a considerable amount of previous research, the results of the consumer tradeoff study demonstrated that levels of cost and levels of services do not compensate for one another. Contrary to current models of traveller choice, the results of the tradeoff analysis clearly show that low cost cannot make up for poor service levels or that good service levels cannot make up for high costs. Rather, results suggest that if service levels are poor (or costs are high) it hardly matters at all what level the cost (or service) attributes are because the service will have very low patronage. Section 4.2, and particularly Figure 4.2, illustrate the situation that emerges from the analysis. For example, the utility curves associated with several levels of fare would all converge as travel time (or any other variable) increased to an unattractive level. If fare and travel time were traded off by individuals, then the utility curves for several levels of fare would be parallel, and at any level of fare, utility would be higher if travel time were lower.

2. The utility of transit compared to auto based on a single model over the entire sample may be expressed as the following linear approximation:

$$U_t = 0.860 + 0.456TS' + 0.78BW - 1.298TH' - .0159F - .000193F^2 - .077WT - .0047T \qquad (1.1)$$

where:

TS' = type of service: 1 if bus, 0 if taxi

BW = bus wait (assumed half the headway), minutes

TH' = cab "headway": 1 if call-ahead, 0 if on-demand

F = fare, cents

F^2 = fare squared, $cents^2$

WT = walk time (2 minutes per block), minutes

T = travel time, minutes.

Two terms with insignificant, small coefficients (WT^2 and T^2) are omitted. As discussed in Chapter 4, a linear model can be used as an approximation to a multiplicative model, which is the most likely "true" model for the Zenia data.

This model shows that:

- Bus service is preferred to even on-demand taxi service, all other variables being equal, by a weight equivalent to a 29-cent fare difference.[1]

- Within the taxi options, the on-demand option is very strongly preferred to the call-ahead option, by a weight equivalent to an 81-cent fare difference.

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[1] This equivalent weight is found by dividing the coefficient of TS' by the coefficient of F (ignoring the F^2 effect).

- Fare has the greatest effect on mode choice of all the level-of-service variables; the elasticity implied by the model's coefficient is close to the -.4 to -.7 range observed in the demonstration.[1]

- Walk time is the next most significant factor for bus service; its "disutility" is 50 percent greater than that of in-vehicle travel time (per minute).

- In-vehicle travel time has very little effect on mode choice; the implied value of travel time based on the model coefficients is only 18 cents per hour.

- Finally, the effect of bus headways is very slight in the range studied; in fact, 30-minute headways were slightly preferred to 15-minute headways.

Travel time difference of public transit over automobile and headway have the least influence of the attributes studied, but their influence differs by trip purpose: headway and transit mode are more influential for work than shopping trips; travel time difference of automobile over transit is more influential for shopping than work trips. Cost appears to have equal influence for work and shopping trips.

3. Results indicate that there are significant differences in the slopes of the cost and level-of-service attributes by demographic and other interpersonal or household characteristics. Some of the differences include the following:

a. Regardless of the type of transit system, its cost or service components, some persons are more disposed to use transit than others. For example, likelihood of using transit decreases slightly

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[1] There is no simple analytic means to derive this elasticity; it emerges from the individual level simulations done for the forecasting phase of this study.

with age. When income is also taken into account, the analysis shows that likelihood of using transit decreases with age in lower-income categories, but increases with age at higher-income levels. Young, low-income individuals are the most likely transit users, followed by older, higher-income individuals. Also, probability of use decreases with increasing auto ownership and is a U-shaped function of adult household size.

b. The influence service type and headway is related to adult household size in a U-shaped manner, indicating that very small and very large households favor bus to paratransit service more strongly than average-size households, though all prefer bus to paratransit service. A person's having previous experience with public transit results in more preference for 15-minute headways compared to 30-minute headways as auto ownership increases. However, persons without previous public transit experience showed no preference for 15- or 30-minute headways regardless of auto ownership. Also, results indicate that older persons are more sensitive to headways than younger persons. Finally, males are considerably more sensitive to paratransit headways than females, strongly preferring on-demand compared to call-ahead service.

c. There are interesting differences in responses to costs of transit service associated with age and sex: older males are less sensitive to cost than females, but younger males are more sensitive to cost than females on the average. There also appears to be an association between low or no auto ownership and increased sensitivity to transit cost.

d. It appears that females are less sensitive to walking distance at all levels of auto ownership compared to males.

e. There appear to be few reliable differences in traveller sensitivity to travel time differences over the ranges studied in Xenia. For example, there are no income differences in reactions to travel time differences.

4. Results indicate that there are differences in how much weight[1] individuals accord cost and level-of-service attributes which are explainable on the basis of sociodemographic and interpersonal characteristics. The following findings can be highlighted:

a. Younger and older individuals place more weight on cost relative to the other attributes examined. Licensed drivers without previous transit experience place more weight on cost than those who have used transit.

b. If an individual has previous transit experience, the weight on walking distance decreases with increasing household size. If an individual has no previous transit use, the weight on walking distance increases with increasing household size.

c. There seems to be a reliable sex difference in weighting of travel time: females place a higher weight on time than males. Weight on travel time increases from ownership of one to two autos and then declines. The sex difference is accentuated when auto ownership

[1] Weight is defined as variance explained by one attribute relative to total variance explained by all attributes.

is also examined: females place more weight on travel time than males with increasing auto ownership up to three autos. The higher weight for females is possibly due to differences in trip purpose, time of day, or destinations, which were not examined.

The results of analyzing user cost and service tradeoffs suggest that these types of results could be used to guide design and implementation of transit demonstration projects as well as to guide or supplement the evaluation of their impacts. The areas in which this technique can be used include:

- Assessment of demand response to parameters with insufficient variability in the demonstration to allow the use of other techniques.
- Improving demonstration design by using the technique, either before implementation or at interim points, to assess the preferences of potential users, and alter the system fare or operating policy to match.
- Providing guidance to marketing efforts by identifying market segments with different responses to system characteristics; this information can be used to decide which aspects of the service should be emphasized to which groups, and what biases may need to be overcome.
- Overall evaluation of a demonstration, by using the technique to allow people to assess their overall satisfaction (more broadly defined than just willingness to use) with the service.

Results of the forecasting and validity tests provide encouraging support for the method and suggest its potential for future application.

The Xenia application provided additional evidence to support the indications of the project results that bus service was preferred to taxi service, and on-demand taxi service was preferred to call-ahead

service. These findings, plus the relatively strong role of fare levels in determining use of transit, were suggested by the project data, but could not be confirmed. This effort, when combined with a thorough validation exercise, is able to give strong answers to these issues.

2. SUMMARY OF DEMONSTRATION

2.1 Overview and Objectives

The Xenia Model Transit Service Demonstration Project was funded by the UMTA Service and Methods Demonstration (SMD) Program. The demonstration served as a test of several alternative transit services operated in a small city setting. Over the course of the demonstration, the system evolved in stages from the original free-fare fixed-route bus system, to a flat-fare fixed-route system, a jitney system, dial-a-ride services operated first in off-peak periods only and then all day, culminating in a mix of differentially-priced paratransit services operated with taxi vehicles.

The system was operated by a public agency during the first half of the project and by a private contractor during the second half. Total funding from all sources for the Xenia project totalled $1,399,739; SMD funding was $655,000.

During the first phase of the demonstration, from July, 1974 through December, 1975 the major demonstration objective was to test the feasibility of providing fixed-route transit service in Xenia. During the demonstration's second phase, from January, 1976 through December, 1977 there were two major demonstration objectives:

1. Demonstrate the technical, operational, and economic feasibility of providing paratransit service as the sole transit service in a small city.
2. Determine the appropriate role for the private sector in the provision of public transportation service.

2.2 Project Setting

Xenia is a city of 8.47 square miles, with a population of approximately 28,600 people, located 13 miles to the east of Dayton, Ohio. The population is predominantly middle-income and the housing stock is comprised largely of single family homes.

Xenia has close economic ties with Dayton; approximately 50 percent of workers residing in Xenia are employed in the Dayton vicinity, and residents travel frequently to destinations throughout the Dayton metropolitan area for shopping and recreational purposes.

The core of the city is small and was severely damaged in the 1974 tornado, when approximately one-quarter of the structures throughout the entire city were destroyed. Recovery from the tornado, in terms of the quantity of rebuilding which occurred, is complete, although the pattern of redevelopment has deviated substantially from plans adopted by the City Commission in June, 1974. Growth has occurred principally in areas at the city's periphery, while a large part of the downtown has not been rebuilt. However, the City has recently approved plans for a shopping mall to be constructed in the vacant section downtown.

2.3 Project History

The initial free-fare fixed-route service was started as a relief measure on April 6, 1974, three days after the city was struck by a tornado. The service operated on half-hour headways on four routes from 6:30 AM to 6:30 PM, six days per week, and on one-hour headways on Sunday. The routes on this service were designed to minimize walk times, and it is estimated that over 90 percent of Xenia residences were located within one-quarter mile of a bus route. The Miami Valley Regional Transit agency operated the service under contract.

SMD funding of the demonstration began on July 22, 1974 though the service remained unchanged until September 1, 1974 when the City's Transportation Department, established with demonstration funding, took over operation of the transit service with Flxette minibuses acquired for the system. A fare of 25 cents was imposed at this time. The route structure in effect during the period of emergency service was retained until November, 1974 when routes were revised to provide more direct access to the downtown area. Routes were subsequently revised again in July, 1975 to accommodate observed travel patterns. Additional system changes in the fixed route phase of the demonstration included the following programs and service innovations: a 24-hour advanced request dial-a-ride service for the handicapped; a pre-paid pass program; a half-fare program for the elderly and handicapped; and the replacement of fixed-route service with dial-a-ride on Sundays and holidays, beginning on July 4, 1975.

The paratransit phase of the demonstration began on January 1, 1976 when the regular fixed-route service was replaced with an unscheduled jitney service during peak hours (7-10 AM and 2-7 PM) and dial-a-ride service during off-peak hours (10 AM - 2 PM). The former route structure was retained on the jitney service. Fares on all services were raised to 50 cents at this time, with senior citizens retaining half-fare privileges on the jitney service. On March 1, 1976, the Xenia Taxi Company entered into contract with the City to operate the service. The private operator increased the base jitney headway from 25 minutes to 1 hour, and extended dial-a-ride service hours until 10 PM. A charter service was also started at this time.

The next major service change occurred on May 9, 1976 when jitney service was eliminated, and shared-ride taxi was instituted throughout the service day. During the week of July 4, 1976, seven-passenger Checker cabs were phased into service, replacing the minibuses and the single taxicab which had previously been in use on the service.

The final service change, which occurred in March, 1977 was a revision of the fare structure, intended to set fares as a function of service levels. Under the revised fare structure, immediate-request shared-ride service was differentiated from advanced-request service, and the latter priced differently during peak and off-peak hours. The fare for immediate-request, shared-ride service was increased from 50 cents to $1. Passengers who requested service at least two hours

in advance would now pay a lower fare than riders using the immediate request service--75 cents during peak hours (7-9:30 AM; 1:30-7 PM), and 50 cents during off-peak hours.

Table 2.1 summarizes data on monthly ridership, operating cost, operating deficits, cost per passenger, and operating ratios for each of the major service types operated over the course of the demonstration. As the table shows, average monthly ridership declined from approximately 40,000 trips for the fare-free emergency service to 6,000 for the mix of paratransit services operated during the last 10 months of the demonstration. Average monthly operating costs ranged from $54,000 during the fare-free period to $17,000 for the jitney service under private management and $19,000 for the paratransit services. The operating deficit ranged from $54,000 (the total operating cost) for the fare-free service, to $12,000 for the paratransit services. The cost per passenger was lowest for the emergency service, at $1.23, and equal to or greater than $2.45 for jitney and paratransit. The operating ratio ranged from 12.5 during the fixed-route period to 2.6 during the paratransit period.

The demonstration ended on December 31, 1977 when the UMTA operating subsidy was discontinued. However, UMTA continued to fund the Xenia Transportation Department from January through June of 1978, while the Greene County Transit Board attempted to develop a plan for continuation of transit service in Xenia. The fare structure was revised on January 1, 1978 in an attempt to cover operating costs in

TABLE 2.1

Operating Statistics for Demonstration Services

	Average Monthly Ridership	Average Monthly Operating Cost	Average Monthly Operating Deficit	Operating Cost per Passenger	Operating Ratio (Cost/Revenue)
Emergency (April - August 1974)*	43,700	$53,697	$53,697	$1.23	--
Fixed Route, 25¢ Fare (September 1974 - December 1975	20,820	35,593	32,757	1.71	12.5
Jitney (Public Management) (January - February 1976)	9,900	24,991	21,767	2.52	7.7
Jitney (Private Management) (March - April 1976)	5,740	17,375	13,532	2.78	4.5
Paratransit (May 1976 - December 1977)**	6,000 - 9,560	19,034	11,723	2.45	2.6

*Although not actually part of the demonstration, data on the emergency free-fare service is included for purposes of comparison. Cost data for the emergency service was estimated from available mileage and per-mile cost data.

**Ridership was 9,560 from May 1976 - February 1977, and 6,000 from March 1977 - December 1977.

the absence of the subsidy. The city was divided into 12 zones, and the fare for travel between zones was set at a minimum of $1, with $1 increments in several steps for longer trips. During this six-month period, average monthly ridership was 2,423, average monthly operating cost was $9,502, and the average monthly operating deficit was $3,537.

Operation of the service was further extended under private operation until September, 1978 when the insurance coverage on the vehicles expired and service was suspended. In January, 1979 Greene County begin providing county-wide transportation services to the elderly using five vans with the Flexicabs as back-up, taking over all transportation functions from the City of Xenia. In April, 1979 county-wide fixed-route and paratransit services for the general public are also slated to begin using the Xenia cab and bus vehicles.

2.4 Conclusions

The service changes implemented over the course of the demonstration provided data for the analysis of a number of important issues. The evaluation findings with regard to each of these issues are discussed below. It should be noted that the evaluation did not begin until the midpoint of the demonstration and thus it focuses on the issues raised in the paratransit portion of the project. Key issues from the fixed-route period are also covered, but in less detail. In particular, many of the interesting travel demand and auto ownership issues during the free-fare and later fixed-route periods could only be addressed indirectly.

1. How do the operating characteristics of the paratransit options compare with the characteristics of fixed-route systems implemented in Xenia?

One of the principal demonstration objectives was to evaluate the feasibility of operating paratransit services in a small city setting. Since both fixed-route and paratransit services were operated during the demonstration, the project provided the opportunity to compare data on level of service, patronage and finances for these different types of service operated at the same location within a short span of time.

A potential advantage of demand-responsive service in a low density setting is that it can accommodate the dispersed trip patterns typical of this form of development while providing users with the convenience of door-to-door service. However, survey results indicate that a high proportion of both fixed-route and paratransit trips in Xenia began or ended downtown. Furthermore, the service levels in terms of travel times, wait times, and walk times were quite similar for the two transit options.

Spatial coverage and reliability were excellent on the fixed-route service as well, again making its service level very comparable to the paratransit system.

In summary, both systems provided average travel times near 15 minutes, wait times near 10 minutes, and short or no walks for the great majority of trips made on the transit system. The average trip length was three miles. This service level was quite good for a small-city setting such as Xenia.

Comparison of ridership data during periods of fixed-route and paratransit service shows that paratransit ridership was only 33 percent of fixed-route levels. Although this decline is partially due to the higher fare charged for the paratransit service, the magnitude of the difference suggests a preference for the fixed-route service. For fare alone to account for the difference between fixed-route and paratransit, the implied fare elasticity would have to be -1.5, a value well in excess of any observed for other Xenia fare changes. Other service level variables, as mentioned previously, were quite similar in the two systems.

Cost per passenger was substantially lower on the fixed-route service than the paratransit service in two eight-month periods of comparison: $1.28 versus $2.12, due both to lower productivity on the paratransit service in terms of passengers per mile, and reduced total ridership. However, the total monthly operating deficit was lower for the paratransit service than the fixed-route service, due to higher fares

and a curtailment of operations in terms of vehicle miles, vehicle hours, and ridership, on the paratransit service. Operating losses were therefore brought closer to a politically acceptable level, although a monthly deficit near $10,000 persisted.

In summary, the evaluation of each system's economic performance depends upon the criteria by which the system is judged. The fixed-route system was operated at a lower cost and deficit per passenger, and with greater ridership. Considering the budget constraint, however, paratransit may be more viable, since higher fares are typically charged for this service, resulting in lower total deficits, and also in lower patronage.

2. <u>What impacts do fare and service changes have on patronage?</u>

Patronage declined throughout the course of the demonstration, due in part to increases in fare. Elasticities were calculated for each of these fare increases; the elasticities ranged from -.51 for the change from free-fare to 25-cent fare, to -1.2 for the change in fare from 25 cents to 50 cents, implemented at the same time the schedule fixed-route bus service was replaced with unscheduled jitney service. In the cases where the fare alone was changed, demand proved to be inelastic. In the single instance where demand proved to be elastic, the apparent explanation is that the simultaneous service change was responsible for some of the decrease in ridership.

A single headway elasticity of -1.5 was computed when jitney headways were changed. A ridership increase of 35 percent occurred when the hourly jitney service was replaced by shared-ride taxi service. Also, during the period when the differentially priced paratransit service was operated, approximately two thirds of the users chose the higher priced immediate-request service ($1) over the less expensive advance-request service (50 cents or 75 cents) even though the advance request travel times were lower as well. These results all indicate that users are more sensitive to service than fare in a small urban area.

A final inference can be made from the fact that paratransit ridership was one third of fixed-route ridership over comparable periods. For fare alone to account for this observed change, the implied fare elasticity would have to be -1.5, a value well in excess of any observed in other Xenia fare changes. Since the measured service attributes of the transit and paratransit systems were essentially the same (travel time, wait time, walk time, and reliability), this comparison also suggests a user preference for fixed-route service over paratransit.

Passengers' perceptions of the tradeoffs between cost and level of service in Xenia are also analyzed in another report, <u>Analysis of User Cost and Service Tradeoffs in Transit and Paratransit Systems</u>.

3. <u>Does the initiation of a new transit service impact auto ownership and travel behavior?</u>

The Xenia demonstration provided the opportunity to assess the degree to which transit availability could influence the course of community development through modification of travel behavior.

One aspect of this analysis is evaluation of the impact of transit availability on auto ownership. Estimates of the percentage of automobiles destroyed in the tornado vary between 16 and 29 percent. Survey results indicate that approximately 90 percent of the households who lost automobiles in the tornado replaced them within one year, and that in subsequent years, auto ownership returned to pre-tornado levels. Thus the demonstration results indicate that transit availability had virtually no effect on auto ownership.

The impact on travel patterns and community redevelopment was also slight due to the fact that transit accounted for only a very small percentage of total trips throughout the demonstration. The intra-Xenia transit modal share ranged from an estimated 4.7 percent in the summer of 1974 to 0.4 percent in the fall of 1977. Mode shares for CBD-bound trips ranged from 7.4 percent to 0.7 percent. Survey results indicate that transit use was proportionately greater among women, persons without driver's licenses, lower income groups, and very large and very small households.

4. <u>How do taxicab vehicles perform on shared-ride paratransit services?</u>

Comparison of cost data for the taxi vehicles and the Flxette minibuses shows that the taxis were more economical to operate on paratransit services. The lower passenger capacity of the taxis had no effect on the number of passengers carried per mile or per hour, and operating cost per mile was lower for the taxis than the Flxettes. Fuel and oil cost averaged 7 cents per mile for the taxis versus 10

cents per mile for the Flxettes. Vehicle reliability, as reflected in maintenance cost per mile, was approximately the same for the two vehicle types: maintenance cost per mile averaged 8 cents for both vehicle types, though maintenance cost would decrease for the taxis relative to the Flxettes if the data were adjusted to account for inflation.

According to a survey of passenger attitudes administered shortly after the introduction of the taxis on the paratransit service, 88 percent of users preferred the taxis to the buses. Respondents to this survey were also asked to rate the ease of entry, noise, smoothness of ride, seating comfort, overall comfort, and privacy of both vehicles; a substantially higher percentage gave the taxis more favorable ratings than the buses.

Hence, it appears that the taxis' performance with respect to both passenger preference and operating economy was superior to that of the buses in paratransit service.

5. How effectively did the mechanics of the contract between the City and the private operator function?

The private operator had some success in reducing direct operating costs, though he/she accomplished this primarily through reductions in service. The operator's flexibility in setting wage rates was another important factor, however. Under private management, drivers' wages were calculated as a percentage of receipts, where previously drivers had received a flat hourly wage.

Administrative cost increased, however, as a consequence of the change in administrative structure resulting from the contract agreement, though this situation was due in part to the project's demonstration status and would not occur under normal system operating conditions. In total, however, the direct operating savings outweighed the added administration costs.

6. How does the introduction of transit service affect a private taxi operation?

Data provided by the owner of the Xenia Cab Company indicate that private taxi revenues declined dramatically during the first two years of the demonstration, when the fixed-route service was in operation. During the subsequent two years of the demonstration, the Xenia Cab Company operated the public transit system under contract. Thus, it appears that competition from a relatively high quality, low-fare public transit service can have a major impact on private taxi operations.

2.5 Implications of Demonstration Results for Other Cities

The major demonstration results are potentially transferable to other small cities with similar demographic and spatial characteristics.

The analysis of data for fixed-route and paratransit services suggests that a fixed-route system can provide service of comparable quality to that of paratransit systems, at lower cost per passenger, depending on the degree to which users' trip destinations are centralize.

Since the percentage of trips with either a downtown origin or destination was high for both fixed-route and demand-responsive service in Xenia (near 70 percent, with one fixed-route survey showing 85 percent), improved access to decentralized locations was not important to most system users. This finding might also apply to other cities where travel purposes and characteristics of transit users are similar to those in Xenia.

The fare elasticities calculated for Xenia transit services tended to be relatively high compared to larger cities, which is probably due to the fact that most transit users either had access to automobiles or could walk to their destinations.

Since a large percentage of Xenia trips had either origin or destination outside the city limits or a reasonably defined transit service area, it is not surprising to find that transit availability had little long-term impact on auto ownership. In other small cities located in metropolitan areas, where the incentive for auto ownership is similarly strong, similar results can be expected. Furthermore, with

high levels of auto ownership, adequate downtown parking, and the absence of significant traffic congestion, the transit modal share is likely to be low, and the impact of the transit system on travel behavior and development patterns minimal. The primary function which transit should reasonably be expected to serve in a city of this type is to increase mobility among those who lack convenient access to automobiles, as well as the elderly and handicapped.

The private operator's success in reducing direct operating costs does not conclusively demonstrate the value of contracts between private operators and the public sector because much of the cost reduction was due to a reduction in service. However, it does suggest that in cases where municipal personnel or administrative policies restrict management options, transit service might be provided more effectively by private operators under contract. In Xenia, this was illustrated by changes in the methods of computing driver wages introduced by the private operator which resulted in a substantial cost decreases.

3. DESCRIPTION OF HOME INTERVIEW SURVEY

3.1 Telephone Screening

A home interview survey was administered to 504 households in Xenia by the City of Xenia in November and December, 1977. There were two phases to the survey--a telephone screening and the home interview. The telephone screening was used to ensure that the sample met pre-established quotas for three criteria: at least 80 percent of the households must have lived in Xenia over the entire 1974-1977 period of the demonstration; at least 20 percent must have used Flexicab; and at least 40 percent must have no more than one auto. These restrictions were imposed to ensure that a sufficient sample was collected of users and low auto-owning households who are potential users: a purely random sample would not have been adequate to cover these groups.

A household found to fit into one of the needed categories was asked whether an interviewer could come to the residence to administer a survey. Figure 3.1 shows the results of the screening process. About half the households in the "outside Xenia or refused to be interviewed" category lived outside the city and were not in the transit service area.

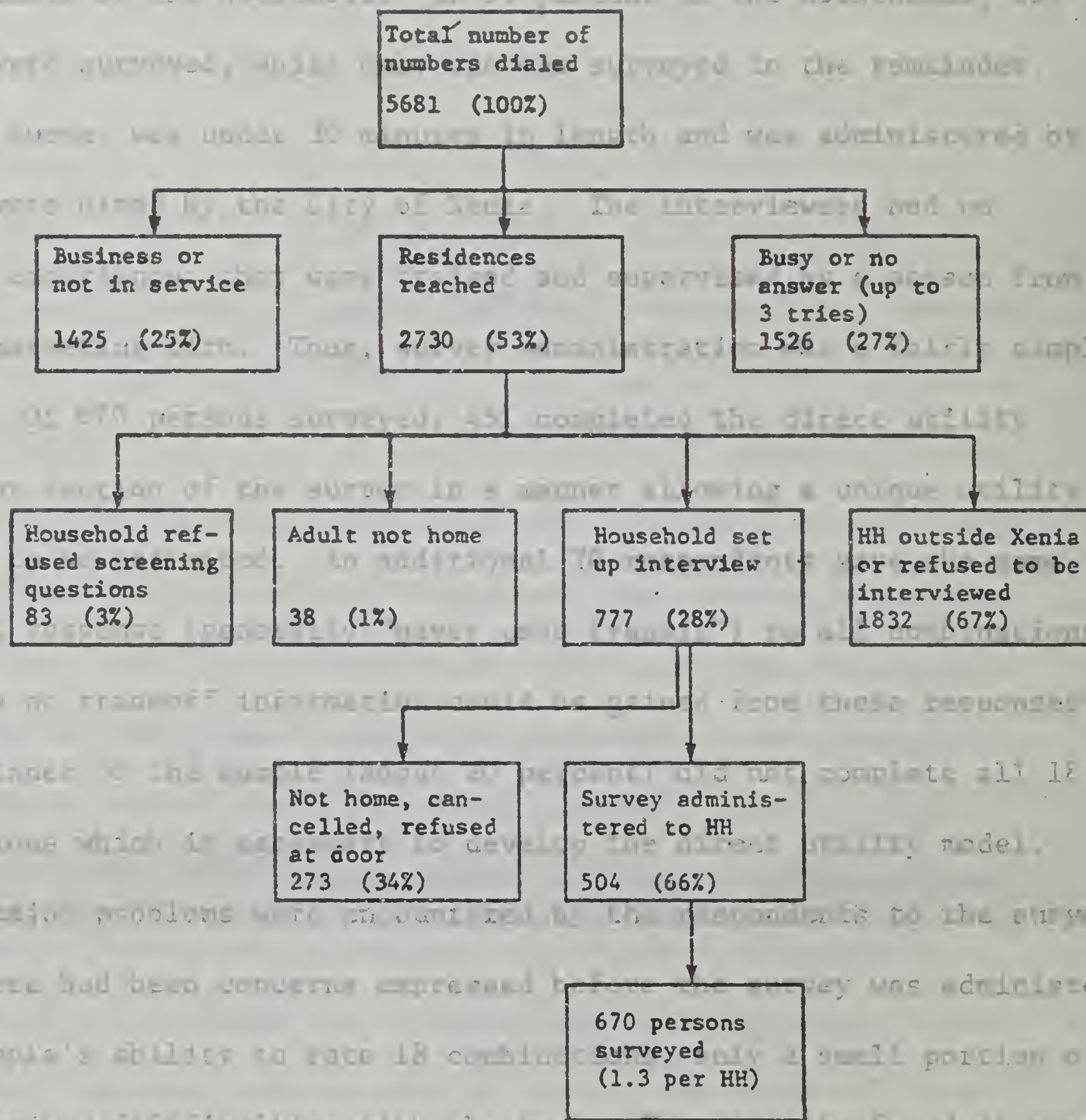

FIGURE 3.1

Results of Phone Screening and Interviewing, 1977

3.2 Home Interview Survey

The home interview survey instrument is included as Appendix C in this report. It consists of four sections. The first asks a series of background questions on the household and the impacts of the tornado on its travel behavior. This section is administered to the head of the household, if possible; the remaining three sections were administered to two persons in the household, if possible. The second portion contains questions on personal characteristics, previous transit usage, and perceptions of auto and transit tradeoffs. The third form is a one-day trip diary used to develop aggregate trip generation, destination, and mode choice statistics to form the data base to attempt to estimate a disaggregate (logit) travel demand model and to provide a data base for forecasting with the direct value assessment procedure described in this report.

Finally, the direct assessment experiment was administered to two persons in the household as the last part of the survey. Eighteen alternatives were listed on a single page, with an 11-point numerical scale beside each (see Appendix C). Each alternative is defined by four variables: type of transit service, cost, walking distance, and travel time. The respondent is asked to rate each of the 18 combinations on the scale according to how frequently he or she might use each. The surveyor explains the instructions in detail for this section of the survey, and may assist in interpreting the first combination. After that, the respondent completes the remainder of the form without

assistance from the interviewer, who is administering the survey to the second member of the household. In 30 percent of the households, two persons were surveyed, while only one was surveyed in the remainder.

The survey was under 30 minutes in length and was administered by interviewers hired by the City of Xenia. The interviewers had no previous experience; they were trained and supervised by a person from a local marketing firm. Thus, survey administration was a fairly simple process. Of 670 persons surveyed, 451 completed the direct utility assessment section of the survey in a manner allowing a unique utility equation to be estimated. An additional 70 respondents gave the same numerical response (generally "never used transit") to all combinations; obviously no tradeoff information could be gained from these responses. The remainder of the sample (about 20 percent) did not complete all 18 combinations which is necessary to develop the direct utility model.

No major problems were encountered by the respondents to the survey. While there had been concerns expressed before the survey was administered about people's ability to rate 18 combinations, only a small portion of the sample had diffficulties with the task. The majority found it easy and were able to complete it in ten minutes or less. Further details on the instrument are included in Appendix C.

4. METHODOLOGY

4.1 Overview of Research Objectives

This component of the Xenia evaluation was designed to focus on data obtained from the responses to the direct utility experiment in the Xenia Home Interview Survey. The experiment contained a set of 18 alternative transit systems that were described by different combinations of type of service and headways, costs, walking distances, and travel time differences of auto over transit. For example, one transit description might be: fixed-route bus service every 15 minutes; 50-cent fare; bus stop located three blocks from the user's home; and travel time ten minutes longer by transit than by auto. Other descriptions contained different combinations of levels for these four attributes. The attribute combinations were selected so that they had the following properties: (1) Each vector or set of attribute values is minimally correlated with every other vector. Had it been possible, the attributes would have been made totally uncorrelated. (2) The levels of the attributes span as much as possible of the variation in actual transit system experience during the Xenia demonstration.

Respondents were instructed that each of these 18 different transit systems either already had been or could be implemented in Xenia. They were then asked how frequently they might use each if each was available. Some respondents were asked for their reactions regarding a work trip to the central business district (CBD); others were asked about a shopping trip to the CBD. Respondents were provided a frequency scale to make

their responses; the scale had five major categories: "never," "rarely," "half the time," "more than half the time," and "all the time." However, as shown on the survey form, an eleven-point scale was used to record the actual responses. The eleven-point scale was chosen as the maximum level of distinctions that could reasonably be made. An odd number is generally used to allow exactly neutral responses (a six on an eleven-point scale) which would not be possible with an even number. The choice of the words "how frequently" to describe the scale may have been unfortunate, as the intent of the study is to examine mode choice. This wording is ambiguous, particularly for shopping trips, and trip generation issues may be confounded with the desired mode choice issues. A better wording would be "how likely are you to use transit." The objective in collecting these responses was to permit the derivation of a unique mathematical expression for each individual to explain his/her responses.

These individual equations express the tradeoffs each individual is willing to make among the four attributes. Based upon previous work with functional measurement, certain methods and analytical procedures discussed later in this chapter were selected to construct the quantitative expressions to describe and explain each individual's tradeoffs. Functional measurement is a theoretical procedure for analyzing multiattribute judgment data of the type obtained in the survey. It is described in Appendix A and will be briefly described in this chapter.

A modification of functional measurement procedures was employed in

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which the usual reliance on factorial or fractional factorial designs (Chapter 4, Section 4.3) was retained, but multiple linear regression was

used as an approximation to the true tradeoff function. Previous work discussed in Dawes and Corrigan (1974) has demonstrated that even if the true function is not a linear, additive equation, a linear regression specification will still capture the rank order of the preferences very well. Thus, if individuals select that alternative which yields the highest expected likelihood of use, it is only necessary to predict the rank order of likelihood of use to predict the number of individuals who will select a particular alternative.

For every individual who completed the experiment in the Xenia Home Interview Survey (and who didn't give the same numerical response to all alternatives, such as never take the alternative), a linear regression equation was estimated that had the following form:

$$L_i = \beta_0 + \beta_1(TS_i) + \beta_2(BH_i) + \beta_3(TH_i) + \beta_4(F_i) + \beta_5(F_i^2) + \beta_6(W_i) + \beta_7(W_i^2) + \beta_8(T_i) + \beta_9(T_i^2) + \varepsilon_i, \tag{4.0}$$

where L_i is the expected likelihood of using any one of the i (=18) transit alternatives;

TS_i is the type of transit system (bus or paratransit);

BH_i is the headway for fixed-route bus (15 or 30 minutes)

TH_i is the headway for paratransit (taxi) system (call-ahead 2 hours or on-demand)

F_i is the level of fare charged (free, 50 cents, $1)
F_i^2 is fare level squared, used to detect non-linearity in the response to fare.

W_i is the level of walk distance to the nearest fixed-route bus system (in front, 3 blocks, 6 blocks). Paratransit was always equal to "in front"; this is the only correlation between attributes in the experiment. W_i^2 is the level of walk squared, used to detect non-linearity in the response to walk.

T_i is the difference in travel time of auto minus transit (same, 10 minutes more, 20 minutes more); T_i^2 is the level of time difference squared, used to detect non-linearity in the response to time.[1]

β_0-β_9 are regression coefficients

ε_i is the error term

The regression equation expressed above as Equation 4.0 is described in detail in Chapter 5. A unique equation of the form of 4.0 was estimated for every respondent who completed the survey which is technically a controlled experiment with sufficient observations to estimate all the coefficients β of Equation 4.0 if all responses are complete. The coefficients of each individual's equation describe how each individual is willing to trade off each of the four attributes. Moreover, any non-linearity in an individual's response to any of the attributes, holding the remaining ones constant (termed the "marginal response") is detectable.

It is important to note at this point that the individual's predicted judgment values are assumed to correspond to the rank order of their choices. Because of this correspondence, choices can be predicted by assuming that whichever of two alternatives is assigned a higher

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[1] These squared terms are technically termed "othogonal polynomials." Orthogonal polynomials are discussed in Appendix B. They are transformations that render x and x^2 uncorrelated to permit efficient estimates to be derived.

numerical score by the individual, then that one would be chosen over the other when both are present. This provides a method for developing a forecasting system based on the analysis of the experimental data. If every individual has an equation and the values of each of the alternatives on each of the important attributes are known, one can generate expected likelihood-of-use values for each alternative for each individual by using their equations. Then by assuming that choice is rank-order related to the predicted likelihood-of-use values, the individual must choose that alternative that yields the highest predicted value. One can then generate an aggregate forecast by simply counting the number of assignments to each alternative, and expanding the sample to the total population.

The forecasting system, therefore, consists of a set of individual linear equations. Each equation has coefficients (Equation 4.0) for the important attributes; and each alternative has a different value for each of the attributes. To forecast aggregate transit shares (or shares for other modes), one substitutes the appropriate attribute levels for a given alternative in each individual's estimated form of Equation 4.0 and generates a predicted likelihood-of-use value. These likelihood-of-use values are compared for each of the available alternatives and it is assumed that each individual chooses that alternative with the highest values. Thus, the choice rule is:

$$P(i|A) = \begin{cases} 1.0 \text{ if } L_i \text{ is max } (L_i) \\ 0 \quad \text{otherwise} \end{cases} \tag{4.1}$$

where

$P(i|A)$ is the probability of the individual choosing alternative i from the set of A available;

L_i is the expected likelihood of use value for i;

$Max(L_i)$ is the maximum of the L_i in A.

This likelihood-of-use value is best thought of as an approximation to that numerical value that the individual respondent would have given on the response scale in the survey had that particular alternative been one of the 18 described.[1] If there are M alternatives, one generates M expected numerical likelihood of use responses. The M values are searched to find the highest value which is used to assign the individual to that alternative. After all individuals have been assigned to an alternative, all individuals assigned to a particular alternative are summed and then divided by the total number of individuals in the sample to obtain an estimate of the aggregate mode share or proportion of total ridership that should be assigned to that mode.

Once these sets of individual coefficients have been estimated, it seems logical to ask whether the coefficients of individuals are related to measures that can be observed on the individual respondents and their households: social, demographic, environmental, experiential, and situational measures. It is hypothesized that differences in coefficients are systematically associated with differences in these interpersonal

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1 Sometimes an alternative will be one of the 18 used in the survey.

measures. There is some data in the home interviews to examine this question, and the results are reported in Chapter 5.

Finally, it seems logical to compare the individual level forecasting system discussed above with a more aggregate approach based on a representative or average individual. Two different aggregate approaches to forecasting were developed:

1. Equation 4.0 was estimated from the average likelihood of use responses calculated for each of the 18 alternatives. It can be shown that the coefficients estimated just on the average responses over all individuals are the same as if they were estimated from all the individual data points, and are the same as the average of the individual coefficients if certain conditions are met, which are approximately met in the Xenia data.[1] Thus, the first aggregation method involves an estimate of the average coefficients of Equation 4.0, which estimates the expected (or average) likelihood of use value across all individuals for each of the alternatives.

2. Equation 4.0 was estimated from the proportion of self-estimated regular users for each of the 18 alternatives. The proportion of regular users is determined by calculating the number of responses of seven (7) or greater on the response scale used in the survey for each of the 18 alternatives. This frequency is converted to a relative

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[1] These conditions are satisfied by balanced combinations of alternatives. This means that all levels of all attributes appear an equal number of times and all attributes are uncorrelated. As will be explained later in Chapter 4, these conditions are almost satisfied in the Xenia data.

frequency of responses seven or greater by dividing the absolute number of sevens or greater for all alternatives. The logic for this adjustment is that if all 18 alternatives were available, the individual obviously couldn't be a regular user (which is what seven or greater on the scale means) of all systems. Thus, the desired measure is the proportion of regular user responses for alternative i relative to all regular user responses for the i alternatives. This interpretation is very similar to the concepts expressed in a disaggregate behavioral choice model (see Domencich and McFadden, 1975). As noted earlier in Section 1.1, this approach is ad hoc, and is based on previous experience which indicates that respondents may overstate their intent to use transit. This approach implicitly adjusts for this effect.

Note that in both aggregation procedures the same functional form of Equation 4.0 is estimated. Only the dependent variable changes in each case. In addition, it was expected that these function forms could be compared with a disaggregate logit demand model regarding their predictive ability. However, because there was little or no variation in the four attributes discussed above in the real Xenia environment, it proved impossible to estimate a logit model that could be compared to these other forms. Hence the only results reported in this document refer to the models based on the direct likelihood of use estimates.

The forthcoming sections review the various analytical methods employed in the research project. The objective of these sections is to

provide a simple introduction to the concepts and methods required to develop tradeoff functions and to analyze data related to such functions. To do this, it is necessary to discuss the following subjects:

1. Direct value assessment is the method by which individuals respond to alternatives and by which their tradeoffs can be directly derived. Derivation of different functional forms is discussed, as is their interpretation.

2. Factorial sampling plans are the method by which the set of alternatives is created for individuals to evaluate. It provides the vehicle to implement the statistical theory of direct value assessment.

3. The Xenia sampling plan is the specific factorial sampling plan employed to implement the direct value assessment method in Xenia. The properties of this plan and their interpretation are discussed.

4. Forecasting procedures from individual tradeoff functions are also described in a brief section.

4.2 Direct Value Assessment: An Overview

Direct value assessment seeks to develop a quantitative expression or model of a single individual's or some group's relative values such as their likelihood to use a set of multi-attribute alternatives. Direct value assessment, therefore, develops a model of the process by which attributes are combined by an individual or group to assign a value to a bundle or collection of attributes. Because any alternative such as a transportation mode can be expressed as a combination (or bundle) of levels of different relevant attributes, the responses of individuals to alternatives can be expressed as values for the attributes (and their levels) of the alternatives. Interest centers on the shape (functional form) of each separate attribute function and the manner by which the individual combines the separate preferences (or values) for the attributes into an overall value for the alternative(s) (the model or specification).

Technically, it is necessary to describe both the marginal and joint value functions. A marginal function refers to the shape or behavior of an individual's responses to a single attribute, while all other attributes are held constant. For example, if cost, type of service and headway, walk distance, and travel time difference are primary attributes which determine choice (or rejection) of travel modes, then the marginal response (or value) for cost would be the shape of the response curve for various levels of cost, while the remaining attributes are held constant at some level. Each attribute has a marginal value

function. An example of various possible marginal value functions is given in Figure 4.1 for the case of cost.

Figure 4.1 depicts marginal preference responses for cost (fare) $P(F_i)$, as a function of cost, F_i. Curve A illustrates a marginal preference response function that decreases at a decreasing rate; i.e., each successive increase in fare leads to less decrease in preference: \$2 is almost equivalent to \$1. Curve B suggests that preferences decrease at an increasing rate; i.e., each unit change in fare leads to increasing declines in preference. Finally, curve C represents a constant decline in preference for any unit change in fare. The shapes of these curves are unique to individuals; however, one can approximate any individual's curve by a polynomial expansion[1] such as:

$$P(A_i) = \beta_{0i} + \beta_{1i} A_i + \beta_{2i} A_i^2 \tag{4.2}$$

where:

$P(A_i)$	is the marginal preference function of A_i;
β_{0i}, β_{1i}, and β_{2i}	are individual value coefficients;
A_i	is attribute i;
A_i^2	is attribute i squared.

In practice, polynomial expansions of degree two (squared, as in the example above) are generally sufficient. Although this modelling strategy has the power to determine unique shapes of marginal response curves for individuals, one can also hypothesize that individuals with

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[1] A technical note in the appendix details polynomial approximations, especially with reference to multiple regression.

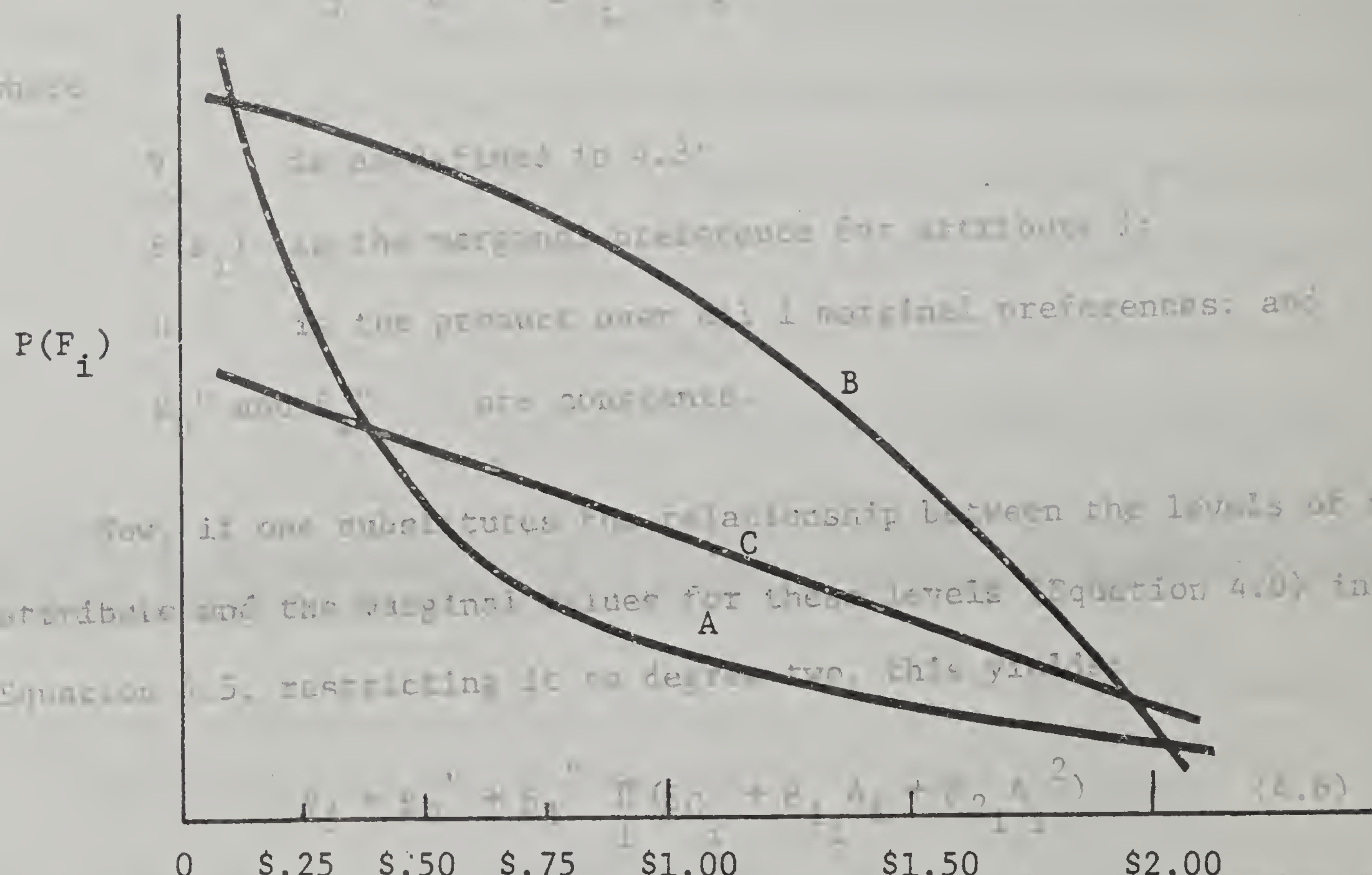

FIGURE 4.1

Alternative Possibilities for the Behavior of Marginal Preferences for Levels of Fare

similarly shaped curves may have similar interpersonal situations and characteristics. The shapes of these curves are determined by the coefficients β_{1i} and β_{2i} in the example above. Thus, if these coefficients can be estimated for each individual, then it is possible to test for differences in these coefficients among individuals as a function of differences in interpersonal characteristics. This is discussed in Section 4.4.

A joint value (or response) function represents the manner in which the separate marginal values are combined to produce an overall value for the bundle (i.e., as noted above, the value or response for an alternative). For example, it is assumed in most travel demand models that the joint function is:

$$V_j = \beta_0' + \beta_1'P(A_1) + \beta_2P(A_2) + \ldots + \beta_N'P(A_N) \qquad (4.3)$$

where

V_j is the value assigned to alternative j (bundle or combination j);

$P(A_i)$ represents the marginal preference responses for attribute i;

$\beta_0', \ldots \beta_N'$ are constants.

In particular, most travel demand models assume that:

$$P(A_i) = \beta_{0i} + \beta_{1i}A_i \qquad (4.4)$$

That is, the marginal value function is assumed to be linear; this is equivalent to assumption C in Figure 4.1. The <u>joint</u> value function is, therefore, also linear and additive in the β's.

Note at this point that almost all potential forms or specifications of interest can be transformed to a linear additive form; hence, the assumption of a jointly additive value specification is not unduly restrictive. For example, if one proposes an alternative form, say multiplication, which often emerges from an analysis of individual to alternatives, this can be written as:[1]

$$V_j = \beta_0'' + \beta_1'' \prod_i P(A_i), \quad (4.5)$$

where

- V_j is as defined in 4.3;
- $P(A_i)$ is the marginal preference for attribute i;
- Π is the product over all i marginal preferences; and
- β_0'' and β_1'' are constants.

Now, if one substitutes the relationship between the levels of an attribute and the marginal values for these levels (Equation 4.0) into Equation 4.5, restricting it to degree two, this yields:

$$V_j = \beta_0'' + \beta_1'' \prod_i (\beta_{0_i} + \beta_{1_i} A_i + \beta_{2_i} A_i^2) \quad (4.6)$$

where all terms are as defined in Equations 4.0 and 4.5. Equation 4.6 states that, if expanded by cross-multiplication, the multiplicative form is actually a jointly additive expression involving single terms (marginals), i.e., expressions in A_1, A_2,...A_i alone; and cross-product terms, i.e., expressions in $A_1 \cdot A_2 \cdot A_3$, etc. The single terms are

[1] Note that in a jointly multiplicative function, any constants on the $P(A_i)$ would "wash out" by common multiplication to some constant such as β_1''.

commonly referred to as "main effects" because they represent the "main" contribution of each attribute, independent of other attributes to the overall preference or value; the latter terms are commonly referred to as "interactions" because they represent any effects that two or more attributes have in combination above and beyond the sum of their main effects. If one considers how preference responses change as one jointly changes fare and headway, the strictly linear additive form of Equation 4.3 states that no matter what the level of fare, a unit change in headway will make a unit change β_2' in the response value, if A_1 is fare and A_2 is headway. By contrast, in Equation 4.6, the contribution of headway to $\bar{V}_j$ differs for different levels of fare. A simple illustration of this is given in Figure 4.2.

Both panels of Figure 4.2 show that cheaper fares are always preferred to more expensive ones and shorter headways to longer; the marginal functions for fare averaged over headways in fact are similar in both panels. To obtain the marginal function for fare, one simply averages the values of $P(F_i,H_j)$ observed at a given value of F_i. In this example, there are three values to average to obtain the marginal function for F_i because there are three levels of H_j (1, 2, and 3) represented by the three curves. The joint functions in panels a and b of Figure 4.2, however, are very different, even though the marginal functions are very similar.

Figure 4.2a shows that there is always a constant difference between the curves at each level of H_j. This suggests that regardless of

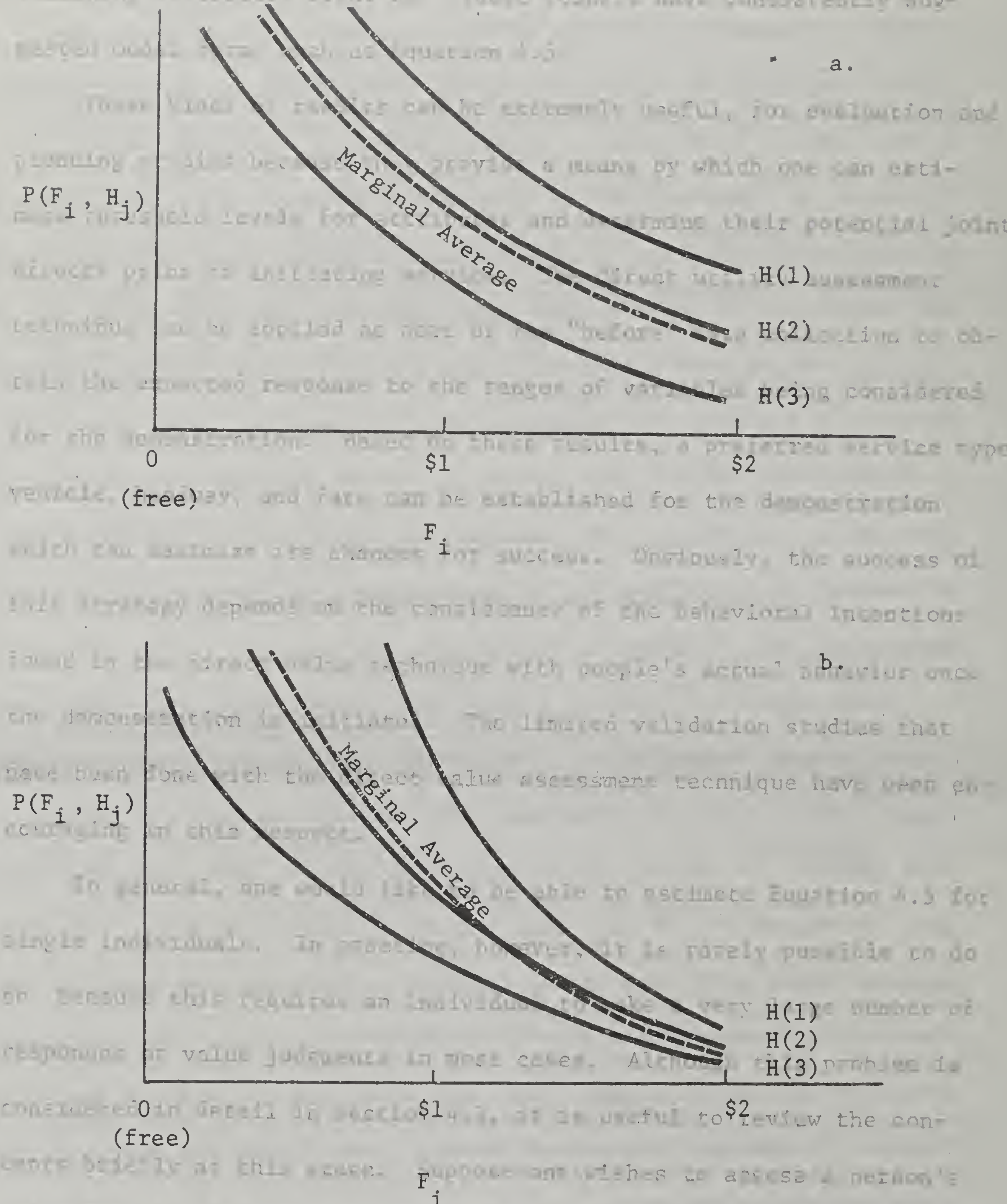

FIGURE 4.2

Additive and Multiplicative Joint Function

$H(1)$ = 15 minutes; $H(2)$ = 30 minutes; $H(3)$ = 60 minutes in headways.
$P(F_i, H_j)$ is the combined or joint preference for combinations F_i and H_j.

the value of F_i, the move from H(1) to H(2) always produces a constant change (at a given point on F_i) in $P(F_i,Hj)$. In fact, this is the very notion of statistical independence--the effects, as measured by the response of $P(F_i,H_j)$ of one or more attributes in combination with one or more other attributes are entirely independent of the levels of one another. This is what one explicitly hypothesizes when one estimates functions like Equation 4.3 in a travel demand model.

By way of contrast, Figure 4.2b shows that there is a non-constant difference between the curves at each level of H_j. Indeed, one might note that as drawn, the difference between each H_j curve is inversely proportional to the value of F_i. That is, as F_i increases, the space between the curves decreases. There is an intuitive way of explaining this preference structure: If F_i is very expensive (very low preference), values of H_j make little, if any, difference; however, as values of F_i improve, differences in H_j begin to matter.

So to illustrate, Figure 4.2a suggests that even beyond $1, good headways can make up for high fares. Figure 4.2b says, beyond $1, almost no improvement in headway can compensate for high fare. Previous studies of individuals (see Louviere, Levin and Norman references) have repeatedly found that Figure 4.2b is a better description than Figure 4.2a for a wide array of attributes in addition to fare and headway. Similarly, it has been found that when three or more attributes are considered simultaneously (jointly), if one attribute is at a very undesirable level, it makes little difference what the values of the

remaining attributes might be. These results have consistently suggested model forms such as Equation 4.5.

These kinds of results can be extremely useful, for evaluation and planning studies because they provide a means by which one can estimate threshold levels for attributes and determine their potential joint effects prior to initiating service. The direct utility assessment technique can be applied as part of the "before" data collection to obtain the expected response to the ranges of variables being considered for the demonstration. Based on these results, a preferred service type vehicle, headway, and fare can be established for the demonstration which can maximize its chances for success. Obviously, the success of this strategy depends on the consistency of the behavioral intentions found in the direct value technique with people's actual behavior once the demonstration is initiated. The limited validation studies that have been done with the direct value assessment technique have been encouraging in this respect.

In general, one would like to be able to estimate Equation 4.5 for single individuals. In practice, however, it is rarely possible to do so because this requires an individual to make a very large number of responses or value judgments in most cases. Although this problem is considered in detail in Section 4.3, it is useful to review the concepts briefly at this stage. Suppose one wishes to assess a person's value function for combinations (or bundles) or fare, headway, walking distance, and travel time differences. One would begin by assigning i

levels to fare, j levels to headway, k levels to walking distances, and ℓ levels to travel time. There would, therefore, be $(i \cdot j \cdot k \cdot \ell)$ total bundles needed to completely specify all joint and marginal functions, plus a second $(i \cdot j \cdot k \cdot \ell)$ or replication set of judgments to yield sufficient variation for an error analysis. For example, if $i = j = k = \ell = 4$, there are 4^4 possible bundles, or 256 total judgments, even without a replication set which would add another 256.

Such a large number of judgments is clearly impractical in applied work. As a result, a number of ways to reduce the total number of judgments required have been developed, which are explored in Section 4.3 (Factorial Sampling Plans). It is sufficient to note that all of these methods for reducing the number of bundles required for judgment result in a loss of some information regarding joint functions. Thus, any reduction in the total number of combinations means that one must make assumptions about the joint functions that cannot be observed. This is, however, not a serious restriction, just as the earlier assumptions of linear and additive values were not restrictive. Appendix A demonstrates that it is always possible to determine the true marginal value functions from a reduced number of alternatives. If one knows the marginal value functions, one can then substitute in Equations 4.3 or 4.5 and test the joint result against the observed judgment data. That specification which fits best across all individuals is accepted as the "best" representation.[1]

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[1] Although it is possible that different individuals have different joint specifications, one usually assumes that all individuals share the group form. In fact, previous work has demonstrated this to be a reasonable assumption.

An alternate way of approaching the problem exists as well (see Dawes and Corrigan, 1974). Specifically, it has been demonstrated that even if a multiplicative form is true, a simpler form such as the linear equation (Equation 4.3) will still correlate very highly with the observed data. In particular, it has been demonstrated that a linear additive specification will reproduce the correct rank order of the observed data, even if the true specification is multiplicative. This can be seen by noting that graphs 4.2a and b imply identical rank orders. Intuitively, this can be understood by noting that as long as the marginal value functions are the same (as drawn in 4.2a and b), a linear function will preserve the approximate rank order.

The above discussion has stressed prediction of "rank order" because this is all that is necessary to predict order of choice. If one assumes that the individual will most frequently select that alternative with the highest predicted value, it is clear that this can be predicted from knowledge of rank order alone. Further, utility theory in economics and psychology merely requires the assumption that utility (or value) and probability of choice are order-related; it makes no statements about the functional relationship, if any. One may, however, turn to discrete choice theory in econometrics for a possible choice of relationship such as the logit model. It has been empirically demonstrated that individual value equations yield values that appear to be related to real world choices in much the same way as logit and other economic models suggest (see Louviere, Wilson, and Piccolo, 1978; Louviere and Levin, 1978; and Louviere and Wilson, 1978).

This is an important conclusion because the remainder of the research relies upon it: if one can estimate a linear value equation for each of a sample of individuals as an approximation to predicting how the values of their responses will vary over bundles of attributes, one can forecast choices over any alternatives that can be characterized by these attributes. Thus, this theory is the basis of the remainder of the research tasks. These tasks are to develop a reduced set of attribute bundles that describe alternative transportation modes, to sample individuals' likelihoods of using responses for each bundle on a numerical judgment scale, and then to predict their most frequent choice of real alternatives by using the attribute levels of fare, headways, walking distance and travel time difference for available modes in each person's equation. The choice prediction consists of assigning each individual to the mode alternative that yields the highest value. Aggregate choice proportions are then obtained by counting the number of assignments to each mode alternative (see Section 4.5).

The next section explores the reduction methodology for simplifying the number of bundles necessary and the development of the forecasting system.

4.3 Factorial Sampling Plans

Modelling individuals' responses to multi-attribute alternatives involves selecting bundles (combinations) of attributes for individuals to evaluate. In a similar manner, the observations of choice employed in traditional transportation data sets consists of bundles of attributes; i.e., combinations of observations of attributes at different levels. Because of the nature of the real world, the vectors of attributes are almost always correlated. For example, auto and transit travel time, auto cost, and transit fare are almost certainly related to distance, and will be strongly correlated for most trips. Moreover, in many cases only a subset of the possible alternatives are available to individuals, also limiting the inferences that can be made. Thus, the sampling plans discussed in this section are extensions of traditional data collection efforts which improve alternative and attribute descriptions over those available in actual data.

It is theoretically possible, although not practical in most instances, for these sampling plans to guarantee independence of all attributes and to permit estimation of a large number of joint effects of these attributes. Such a possibility would be realized by conducting one or more of a number of possible controlled experiments. For example, various bus systems could be developed as combinations of fare, headway, and walking distance to bus stop. If one assumes that two levels are allowed for each attribute (e.g., fare--25 cents, 50 cents; headways--every 15 minutes, every 30 minutes; walking distance--3 blocks or less,

more than 3 blocks), there are eight possible bus systems given by these combinations as shown in Table 4.1. Note that each combination provides information regarding all of the attributes. This sampling plan is very effective because it provides information about all separate (marginal) effects and all joint (interaction) effects. As stated previously, a factorial experiment consisting of all combinations of all variables is required in order to be able to estimate all possible main effects and interactions. The approach to using this kind of plan from which the present study is derived, is to present individuals with sets of alternatives similar to those in Table 4.1 and have them express some response of interest, such as preference or likelihood of use. This permits one to simulate the same experiment, as if it has been run in the real world. The term for this kind of sampling design, or experimental design, is a factorial design. It is called a factorial design because <u>all</u> combinations of <u>all</u> levels of <u>all</u> attributes are employed. Technically, the sampling design in Table 4.1 is a 2^3 factorial. If one assigns each attribute a third level, say $1 for fare; every 60 minutes for headway; 0 - 3 blocks, 3 - 6 blocks, more than 6 blocks for walking distance, the design would become a 3^3 factorial, or 27 alternatives.

It should be clear that as one increases the number of attributes or the number of levels, or both, the total number of possible combinations grows rapidly. Two examples of this problem might be five attributes at three levels which is a 3^5 or 243 combinations, or an asymmetrical design

TABLE 4.1

Factorial Combinations in Bus Service Example

System	Fare	Headway	Walking Distance
1	25¢	15 minutes	< 3 blocks
2	25¢	15 minutes	> 3 blocks
3	25¢	30 minutes	< 3 blocks
4	25¢	30 minutes	> 3 blocks
5	50¢	15 minutes	< 3 blocks
6	50¢	15 minutes	> 3 blocks
7	50¢	30 minutes	< 3 blocks
8	50¢	30 minutes	> 3 blocks

such as a 4 x 3 x 2^7, or 1536 combinations. (Designs in which all attributes are at the same number of levels are termed symmetric; all others are asymmetric.) As a result of this property of factorial designs, one will usually want to use considerably less than all possible combinations, given any set of attributes and their levels of interest. This requires that one understands the methods available for reducing the number of combinations required; these are termed "fractional factorial designs."

4.3.1 Fractional Factorial Sampling Designs

If one is interested in estimating value functions as described in Section 4.2, the following questions must be answered before any design can be selected (see Green, 1974):

a. What type of information does one require for modelling purposes:

   i) main effects only
   ii) main effects plus selected interaction effects
   iii) all main and interaction effects

b. What is the nature of the levels of each attributes?

   i) all attributes have equal numbers of levels
   ii) different attributes have different levels

c. How many attributes does the researcher want to vary in any single set of combinations?

   i) all attributes
   ii) some subset of attributes

Question (a) essentially determines the complexity of the information one can obtain from the individual: (i) yields the least information,

essentially equivalent to providing information about the marginal response values only; (ii) yields more information than (i), in that it permits one to examine selected joint value terms; (iii) provides complete information, but is rarely practical. Question (b) concerns whether one can employ a symmetric or asymmetric fractional design. Although it is easier to obtain symmetric designs in available sources, a catalog produced by Hahn and Shapiro (1966) covers a very wide range of both types of designs and should ordinarily suffice. Question (c) is included only because some transportation researchers have advocated using designs that present less than all attributes at a time. In particular, one type of design in which attributes are varied two at a time (called tradeoff analyses) has been frequently employed (e.g., see Eberts and Koeppel, 1977).

Question (c) is not discussed in this study, as plans to do not permit, all of the factors simultaneously (or at least a large subset) have significant disadvantages. Therefore, only Questions (a) and (b) are considered truly relevant to the design of a direct response or value assessment study. It is impossible to provide a general rule for the selection of fractional designs and it is recommended that the interested researcher examine some basic texts, such as Winer (1973) or Cochran and Cox (1957). An excellent cookbook to guide selection of plans for any specific problem is provided by Hahn and Shapiro (1966).

As a rule of thumb, a common multiple that is larger than the sum of each of the levels minus the number of attributes represents a potential plan that is at least a main-effects plan. For example, if one has seven attributes with the following levels 4 x 3 x 3 x 4 x 2 x 2 x 2 (= 1,152 combinations), then common multiple of potential interest are 24, 36, and 48 (one certainly would not want more than 48!). Twelve is not possible because there are an insufficient number of observations to estimate all main effects (4 + 3 + 3 + 4 + 2 + 2 + 2 - 7 = 13). Thus, 24 combinations is the minimum design, and will allow some interactions to be estimated; 36 and 48 would allow more interactions to be analyzed.

It is frequently desirable to develop designs which provide that all main effects and two-way interactions can be estimated independently of one another and all other interaction effects. To illustrate this idea, consider a 3 x 3 x 3 sampling plan. The levels are labelled 1, 2, and 3. The full design is given in Table 4.2 for hypothetical attributes A, B, and C. If one wishes to fractionate this design so that one can infer the main effects of A, B, and C, one needs to know which terms or effects are correlated with which others. For example, if one wants to estimate the main effects independently of one another, it is obviously desirable that all main effects be uncorrelated with each other. So, one would want to choose a fractional sampling plan that guaranteed this independence. Likewise, if one suspected that there would be significant interaction effects, one would want to try to minimize correlations with these effects as well. As a rule of thumb, less and less variation is accounted for by interactions after main effects have been accounted for,

TABLE 4.2

Full Factorial Coding Example

A	B	C	A	B	C	A	B	C
1	1	1	2	1	1	3	1	1
1	1	2	2	1	2	3	1	2
1	1	3	2	1	3	3	1	3
1	2	1	2	2	1	3	2	1
1	2	2	2	2	2	3	2	2
1	2	3	2	2	3	3	2	3
1	3	1	2	3	1	3	3	1
1	3	2	2	3	2	3	3	2
1	3	3	2	3	3	3	3	3

even if the interactions are significant. It is usually the case, in fact, that two-way (e.g., A x B) interactions account for less variance than main effects, but more than three-way interactions (e.g., A x B x C). Hence, one usually wants to collapse across as many interaction effects that are three-way or larger as possible. In fact, one tries to minimize correlations with two-way effects because these could be large and affect interpretation of results.

To understand how one selects such a fraction, it is instructive to return to a multiple linear regression format. For the design in Table 4.2, the following regression equation may be specified.

$$V_i = \beta_0 + \beta_1 A_i + \beta_2 A_i^2 + \beta_3 B_i + \beta_4 B_i^2 + \beta_5 C_i \tag{4.7}$$

$$+ \beta_6 C_i^2 + \beta_7 A_i \cdot B_i + \beta_8 A_i \cdot B_i^2 + \beta_9 A_i^2 \cdot B_i$$

$$+ \beta_{10} A_i^2 \cdot B_i^2 + \beta_{11} A_i \cdot C_i + \beta_{12} A_i \cdot C_i^2$$

$$+ \beta_{13} A_i^2 \cdot C_i + \beta_{14} A_i^2 \cdot C_i^2 + \beta_{15} B_i \cdot C_i$$

$$+ \beta_{16} B_i \cdot C_i^2 + \beta_{17} B_i^2 \cdot C_i + \beta_{18} B_i^2 \cdot C_i^2$$

$$+ \beta_{19} A_i \cdot B_i \cdot C_i + \beta_{20} A_i \cdot B_i \cdot C_i^2 + \beta_{21} A_i \cdot B_i^2 \cdot C_i$$

$$+ \beta_{22} A_i \cdot B_i^2 \cdot C_i^2 + \beta_{23} A_i^2 \cdot B_i \cdot C_i$$

$$+ \beta_{24} A_i^2 \cdot B_i \cdot C_i^2 + \beta_{25} A_i^2 \cdot B_i^2 \cdot C_i$$

$$+ \beta_{26} A_i^2 \cdot B_i^2 \cdot C_i^2 + \varepsilon_i ,$$

where:

$\beta_0 - \beta_{26}$ are regression coefficients (a total of 27: one constant, 6 main effects, 12 two-way interactions, and 8 higher-order terms);

A_i is the linear effect of Factor A; A_i^2 is its quadratic effect;

B_i is the linear effect of factor B; B_i^2 is its quadratic effect;

C_i is the linear effect of factor C; C_i^2 is its quadratic effect;

All remainging terms are the cross-products or interaction effects of the above three factors.

In order to create a fraction which has the properties discussed in the preceeding paragraphs, one would usually want to select a sampling plan that leaves A_i, A_i^2, B_i, B_i^2, C_i and C_i^2 uncorrelated with one another and uncorrelated with as many of the two-factor cross-products (interactions) as possible. In fact, one usually tries to collapse such that terms like β_{19} through β_{26} are correlated with one another and some of the β_7 through β_{14} terms, but not with the β_1 through β_6 terms. This permits one to get estimates of the main effects (β_1 through β_6) unconfounded by correlations with other potentially highly significant terms.

However, in order to obtain efficient estimates of these terms, one needs to be able to specify A and A^2, B and B^2, and C and C^2 in such a way that they are uncorrelated. In this case a factorial or fractional factorial sampling plan is a necessary but not sufficient condition to guarantee this independence. Unless one can transform A, B, and C into separate uncorrelated linear and quadratic terms, A and A^2 will be correlated, as will be B and B^2 and C and C^2. The creation of independence is accomplished by means of a transformation procedure termed the "method of orthogonal polynomial transformations." This method is discussed in Appendix B; briefly, it consists of a mathematical function to transform the levels of any factor into terms that represent linear and squared effects and which are independent. This method is used in the research tasks to insure independence of main linear and quadratic effects in analyzing the responses to the Xenia sampling plan.

For example, in Table 4.2, one can use the method of orthogonal polynomials to create all the terms of interest by replacing the codes in Table 4.2 with the following:

a. For a linear effect, wherever the value "1" appears, replace it with "-1"; replace "2" with "0"; replace "3" with "1"

b. For a quadratic effect, wherever the value "1" appears, create a value of a new vector equal to "1"; for the level "2," create a value of "-2"; for the level "3," create a "1"

These new codes are given in Table 4.3. In Table 4.3, L stands for a linear effect; Q for a quadratic effect. Note that in each column the sum of the elements of the vector equals zero. The correlation between each pair of vectors is zero. The cross-product, A(L) · B(L) is formed simply by multiplying each pair of elements within a row (observation); thus, the first observation under A(L) is -1, and under B(L) is -1; their cross-product is A(L) x B(L), or (-1) x (-1) = +1. All cross-products are formed in the same way.

Table 4.3 shows that there are six independent main effects which can be estimated; similarly, by expansion, one could find 20 interaction terms, all of which are independent. This is possible because the full factorial design, 3^3 or 27 combinations, is used. The 27 observations are sufficient to estimate 27 coefficients, although no degrees of freedom remain for estimating error. Now consider the effect of taking a one-third fraction of 9 combinations from the total 27; an example of a one-third fraction is given in Table 4.4.

All of the terms shown in Table 4.4 are independent of each other; however, <u>they are not independent of other terms not shown</u>. For example,

TABLE 4.3

Orthogonal Coding of the Design of Table 4.2

Main Effects						Some Example Interactions		
A(L)	A(Q)	B(L)	B(Q)	C(L)	C(Q)	A(L)B(L)	B(Q)C(L)	A(Q)B(Q)C(L)
-1	+1	-1	+1	-1	+1	+1	-1	-1
-1	+1	-1	+1	0	-2	+1	0	0
-1	+1	-1	+1	+1	+1	+1	+1	+1
-1	+1	0	-2	-1	+1	0	+2	+2
-1	+1	0	-2	0	-2	0	0	0
-1	+1	0	-2	+1	+1	0	-2	-2
-1	+1	+1	+1	-1	+1	-1	-1	-1
-1	+1	+1	+1	0	-2	-1	0	0
-1	+1	+1	+1	+1	+1	-1	+1	+1
0	-2	-1	+1	-1	+1	0	-1	+2
0	-2	-1	+1	0	-2	0	0	0
0	-2	-1	+1	+1	+1	0	+1	-2
0	-2	0	-2	-1	+1	0	+2	-4
0	-2	0	-2	0	-2	0	0	0
0	-2	0	-2	+1	+1	0	-2	+4
0	-2	+1	+1	-1	+1	0	-1	+2
0	-2	+1	+1	0	-2	0	0	0
0	-2	+1	+1	+1	+1	0	+1	-2
+1	+1	-1	+1	-1	+1	-1	-1	-1
+1	+1	-1	+1	0	-2	-1	0	0
+1	+1	-1	+1	+1	+1	-1	+1	+1
+1	+1	0	-2	-1	+1	0	+2	+2
+1	+1	0	-2	0	-2	0	0	0
+1	+1	0	-2	+1	+1	0	-2	-2
+1	+1	+1	+1	-1	+1	+1	-1	-1
+1	+1	+1	+1	0	-2	+1	0	0
+1	+1	+1	+1	+1	+1	+1	+1	+1

TABLE 4.4

1/3 Fractional Plan, Polynomially Coded

Main Effects						Some Two-Way Interactions						
A(L)	A(Q)	B(L)	B(Q)	C(L)	C(Q)	AB	AB^2	A^2B	A^2B^2	AC	BC	ABC
-1	+1	-1	+1	-1	+1	+1	-1	-1	+1	+1	+1	-1
-1	+1	0	-2	+1	+1	0	+2	0	-2	-1	0	0
-1	+1	+1	+1	0	-2	-1	-1	+1	+1	0	0	0
0	-2	-1	+1	+1	+1	0	0	+2	-2	0	-1	0
0	-2	0	-2	0	-2	0	0	0	+4	0	0	0
0	-2	+1	+1	-1	+1	0	0	-2	-2	0	-1	0
+1	+1	-1	+1	0	-2	-1	+1	-1	+1	0	0	0
+1	+1	0	-2	-1	+1	0	-2	0	-2	-1	0	0
+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1

$AC = AB^2C$ and $AB = ABC^2$. This can be found by the multiplication of the corresponding columns in Table 4.3. In general, the sum of the inner products of two vectors must be zero for them to be independent of one another. Many of the possible terms not shown in Table 4.3 fail to meet this criterion. Thus, one could estimate an effect or coefficient for AC or AB, but one would not be able to ascribe the coefficient to either effect. Note that in traditional demand data there will rarely be observations over all possible combinations, nor will there be balance in the number of observations of each level of each factor. Thus, traditional travel demand data constitutes a non-orthogonal (non-independent) sampling plan with some effects confounded in a manner which cannot be determined prior to data collection. After data collection, an analysis of the independent variables in the data set could be performed to examine which main effects and interactions were estimable, as if the data were an experiment. In practice most of the interactions would be confounded, and perhaps even some main effects. On the other hand, factorial sampling plans permit one to know a priori what the confoundment structure is and what effects can be reliably estimated.

4.3.2 The Xenia Sampling Plan

The particular sampling plan employed to derive combinations (alternatives) in the Xenia study represents one of many possible "main effects only" plans and also represents a compromise for the sake of realism. There were four factors of interest in the Xenia design: (1) headway and mode of operation; (2) fare; (3) walking distance; and (4) travel time differences. These attributes were given values to generally cover

the range of past, current and near-future term possibilities in Xenia. Thus, the following levels were selected:

1. Headway and mode

   a. Bus:

      (1) every 15 minutes
      (2) every 30 minutes

   b. Taxi:

      (1) call-ahead two hours
      (2) on-demand, immediate call

2. Fare:

   a. free

   b. 50 cents

   c. $1

3. Walking Distance to Transit from Home[1]:

   a. in front (0 blocks)

   b. 3 blocks

   c. 6 blocks

4. Travel Time Difference Between Transit and Auto:

   a. same by transit and auto

   b. 10 minutes longer by transit than by auto

   c. 20 minutes longer by transit than by auto

Technically, this is a 4 x 3 x 3 x 3 factorial design with headway nested within type of service. Hence, the effect for type of service (bus, taxi) and headway nested within it contains four levels. There are 108 total possible combinations in a complete design with these factors.

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[1] Walking distance at destination was assumed to be small.

Note, however, that whenever the transit service is taxi, walking distance must be zero. Thus, walking distance can be eliminated from all taxi combinations, so there are technically 2 x 3 x 3 x 3 bus combinations and 2 x 3 x 3 taxi combinations, or 72 instead of 108. Nonetheless, this is a large number of combinations and it was felt that a maximum of 20 for this trial of the method was appropriate.

A compromise sampling plan was selected that employed 18 of the 72 combinations (see Table 4.6) in such a way that if desired, separate bus and taxi response functions could be estimated for each respondent. Thus, within a type of service level (bus, taxi) each attribute vector is independent of every other attribute vector, but between types of service there is a consistent correlation with walking distance because of the requirement that all taxi combinations have zero walking distance. (In most applications of this technique, there would be no correlations among any variables.) The correlation matrix for these attributes for all 18 combinations is given in Table 4.5, which contains nine effects or terms. These terms arise because it is possible to partition the variation (as in an analysis of variance) in a dependent response measure into "main" and "interaction" effects. For example, it can be shown that the sum of the squared deviations (sum of squares of SS) about the mean of the dependent response (termed the "total sum of squares" or sum of all the squared deviations) can be partitioned in the following manner if all 108 combinations are used:

$$\text{Total Sum of Squares} = \text{SS (main effects)} + \text{SS(interaction effects)} + \text{SS(error)} \qquad (4.8)$$

TABLE 4.5

Correlation Matrix of Effects in Xenia Design

	TS	BH	TH	F	W	T	F^2	W^2	T^2
TS	1.000000	-0.07881	-0.07881	0.0	0.65465	0.0	0.0	-0.44721	0.0
BH	-0.07881	1.00000	0.00621	0.0	-0.05159	0.19305	0.44582	0.59917	0.11146
TH	-0.07881	1.00000	1.00000	0.0	-0.05159	0.0	0.22291	0.03525	0.22291
F	0.0	0.0	0.0	1.00000	0.0	0.0	0.0	0.0	0.0
W	0.65465	-0.05159	-0.05159	0.0	1.00000	0.0	0.0	-0.29277	0.0
T	0.0	0.19305	0.0	0.0	0.0	1.00000	0.0	0.0	0.0
F^2	0.0	0.44582	0.22291	0.0	0.0	0.0	1.00000	0.0	0.0
W^2	-0.44721	0.59917	0.03525	0.0	-0.29277	0.0	0.0	1.00000	0.0
T^2	0.0	0.11146	0.22291	0.0	0.0	0.0	0.0	0.0	1.00000

TS - type of service
BH - bus headway
TH - taxi "headway"
F - fare
W - walk distance
T - travel time difference from auto

These sums of squares can be expressed as additive terms as follows for the Xenia design:

SS(main effects) = SS(headway and mode of operation) (4.8a)
+ SS(walking distance to stop)
+ SS(fare)
+ SS(travel time difference transit/auto)

SS(interaction effects) = SS(headway and fare) (4.8b)
+ SS(headway and walking distance to stop)
+ SS(headway and travel time)
+ SS(fare and walk)
+ SS(fare and time)
+ SS(walk and time)
+ SS(headway and fare and walk)
+ SS(headway and fare and time)
+ SS(headway and walk and time)
+ SS(fare and walk and time)
+ SS(headway and fare and walk and time)

Because there are only 18 of the 108 total combinations, it is not possible to estimate all of these effects. Specifically, one must sacrifice all of the interaction effects because the particular 18 combinations selected have the property that all interaction effects are so highly correlated that it is virtually impossible to distinguish one from another. However, the main effects can be expressed as nine terms in a multiple regression equation. The nine terms arise because one can estimate a number of terms <u>within each main effect</u>. In fact, the number of terms one can estimate ie equal to the number of levels within a main effect minus one. Thus, if there are ℓ levels within an attribute, the main effect of that attribute requires $(\ell - 1)$ terms in a multiple

regression equation to be completely specified.[1] Recalling the number of levels for the Xenia design, there are four for headway and mode of operation, three for cost, three for walking distance, and three for travel time. Applying the (ℓ - 1) rule, there are three terms in headway/mode, two in cost, two in walk and two in time, or nine.

Thus, each of the sums of squares listed in equations 4.8a and b constitutes an effect, and each is uniquely and independently estimable if data are obtained over the entire factorial design. In essence, the F-tests of analysis of variance (or those for multiple regression) test the ratio of the sum of squares contributed by each term to the total sum of squares against zero or some measure of pure error. A multiple linear regression model can provide additional information beyond that of the analysis of variance test of the effects because it provides an inference regarding shape or form of the functions. The reason for this is because each of the sums of squares in Equation 4.8 can be decomposed into separate and independent (additive) regression terms. For example, one can write out the main effects (those sums of squares terms with no cross-products) as follows:

---

1 The reason for this can be understood as follows: (a) if there are two levels of a factor, there are in effect two data points. Two data points can be exactly fit by one straight line or one term (coefficient); (b) if there are three levels, there are three data points and these can be exactly fit by a linear plus a squared term. Hence, the number of levels (data points) minus one determines the number of terms.

$$SS\ (total) = \beta_0 + \beta_1 \cdot (TS) + \beta_2 \cdot (BH) + \beta_3 \cdot (TH) + \beta_4 \cdot (F) + \beta_5 \cdot (F^2) + \beta_6 \cdot (W) + \beta_7 \cdot (W^2) + \beta_8 \cdot (T) + \beta_9 \cdot (T^2) + \varepsilon \qquad (4.9)$$

where $\beta_o - \beta_a$ = coefficients and the variables are as defined in Table 4.5.

A separate regression coefficient can be estimated for each of the (ℓ - 1) terms in each attribute. Headways and mode of operation is decomposed into β_1 for type of service (bus or taxi); β_2 for "if bus and every 15 minutes (or every 30 minutes)"; β_3 for "if taxi and on demand (or call-ahead)". Similarly, β_4 is the coefficient for the linear effect of cost, β_5 is for its quadratic, β_6 is for the linear effect of walking distance, β_7 is for its quadratic; β_8 is for the linear effect of travel time, and β_9 is for its quadratic. So, for example, if the marginal relationship (holding other factors or attributes constant) between the dependent response (likelihood to use) and cost is linear, β_4 should be statistically significant, while β_5 should not.

In a like manner, one can decompose any cross-product or interaction effect into separate, independent components for estimation. Thus, if attribute A has a levels and attribute B has b levels, there are always (a - 1)(b - 1) separate terms which can be estimated. Similarly, if there is an attribute C with c levels, there are (a - 1)(b - 1)(c - 1) possible separate three-way terms which can be estimated. Thus, for cost (F) and walking distance (W) we would have:

$$\text{SS (F and W interaction)} = \beta_1 \cdot (F \cdot W) + \beta_2 \cdot (F \cdot W^2) + \beta_3 \cdot (F^2 \cdot W) + \beta_4 \cdot (F^2 \cdot W^2) + \text{error} \tag{4.10}$$

where

β's	are separate coefficients
$F \cdot W$	is the linear x linear portion of the interaction effect
$F \cdot W^2$	is the linear x quadratic portion of the interaction effect
$F^2 \cdot W$	is the quadratic x linear portion of the interaction effect
$F^2 \cdot W^2$	is the quadratic x quadratic portion of the interaction effect.

There would be eight terms in a three-way interaction among variables having three levels, as shown by terms β_{19} through β_{26} in Equation 4.7.

Thus, similar to a main effect, any interaction may be decomposed into separate additive polynomials such as those in Equation 4.10. Note that there are exactly as many terms as the product $(\ell_e - 1) \cdot (\ell_2 - 1)$, or the product of the levels minus one. To truly estimate and diagnose a unique model form for each individual requires the individual to respond to all the combinations in a factorial design. However, this is rarely possible. In the case of the Xenia design, many less than all possible combinations were desired so that respondents could complete all responses without problems. However, it was also necessary to select a sufficient number of combinations so that information about the main effects could be obtained.

The Xenia sampling plan, which consists of 18 combinations, represents a one-sixth fraction of the total design. The design is not a regular fraction. A regular fraction is one in which the number of levels are balanced in how frequently they appear. For example, the level of walking distance in front appears in 12 out of the 18 combinations; 3 blocks and 6 blocks only appear three times each. Thus, walk levels are unbalanced and the coefficients for walking distance are not independent of type of service of headways within type of service. However, if one analyzes each type of service separately, both fractions are regular and balanced.

Because there are only 18 out of all 108 combinations, it is clearly not possible to estimate <u>all</u> of the effects contained in Equation 4.8, or the regression coefficients represented in Equations 4.9 and 4.10 as noted above. This point is important because it also bears on the limitations of traditional transportation demand data. Designs such as the 18-combination Xenia plan are commonly referred to as "confounded" or "aliased" designs. These expressions are particularly descriptive of the situation. Many of the terms in the regression equation would be perfectly correlated ($r = 1.0$) and, therefore, the interpretations of one term is confounded by its perfect correlation with another term. In this situation, only one term of the correlation group can be estimated, and it cannot be known <u>which</u> of the several perfectly correlated effects it stands for. This confounding occurs because one collapses the full factorial design over most of the interactions in order to

develop fractions. Typically, one desires to develop fractions such that the main effects are as uncorrelated as possible with any other effects; that is, such that main effects can be estimated totally independently of all other effects. In this situation one sacrifices many, if not all, interaction (cross-product) effects by confounding them with one another. Many interaction terms are perfectly correlated with others and, therefore, their estimation provides little information.

The Xenia design has nine main effect terms as noted in Equation 4.9; however, it is not completely orthogonal nor is it exactly balanced. Thus, the confounding pattern is more difficult to estimate than in the example of Table 4.4. Yet the pattern of estimates is still relatively straight-forward and can be determined <u>a priori</u>. This is important because in contrast to traditional analyses of travel choice data, the <u>exact</u> analytical structure is known in advance. Furthermore, because all respondents face the same alternatives and the same analytical structure, they all can be compared.

The combinations for each type of service are listed in Table 4.6. It can be readily observed that all 50-cent levels of fare occur within the 15-minute level of headway. Effectively, this means that no estimate of the middle effects of either fare or headway can be estimated in an interaction. Similarly, all observations of 3 blocks occur within the 15-minute level of headway. Hence, the middle level of walk is similarly biased. Only travel time displays sufficient variation to permit the middle level to be examined. In the case of the taxi

combinations, sufficient variation occurs within both fare and travel time across headway to allow an examination of the interaction structure. In both cases, however, it should be noted that each interaction cell has only a single observation; it is not a very reliable test in this respect, either. These problems were not envisioned in the design of the experiment, but occurred because such a large emphasis was placed on minimizing the number of alternatives. A design of 27, which would have avoided these problems, would have been preferred and has proved feasible in other real-world applications.

TABLE 4.6

Combinations within Types of Service for the Xenia Design

	BUS PLAN				TAXI PLAN		
	Headway	Fare	Walk	Time	Headway	Fare	Time
1	15 min.	free	3 blk	+10 min.	On Demand	free	+10 min.
2	15 min.	50¢	6 blk	same	On Demand	50¢	same
3	15 min.	50¢	in front	+10 min.	On Demand	50¢	+20 min.
4	15 min.	50¢	3 blk	+20 min.	On Demand	$1.00	+10 min.
5	15 min.	$1.00	3 blk	same	Call Ahead	free	same
6	30 min.	free	in front	same	Call Ahead	free	+20 min.
7	30 min.	free	6 blk	+20 min.	Call Ahead	50¢	+10 min.
8	30 min.	$1.00	6 blk	+10 min.	Call Ahead	$1.00	+20 min.
9	30 min.	$1.00	in front	+20 min.	Call Ahead	$1.00	same

4.4 Analytical Techniques for Model Specification

Bearing the caveats about confounding in mind, one can attempt a graphic representation of the data to illustrate both the notion of main effects and interactions. As explained in the formal development of direct value assessment, knowledge of these various effects leads directly to model specification because it pinpoints the appropriate functional form. As an example, if the four attributes combine linearly, then no interactions can be significant. This is equivalent to the expectation that plotting the response surface for headway at various levels of fare (or vice versa) would yield a series of parallel curves. If the model is strictly additive, each attribute contributes a constant amount to the response independent of the remaining attributes. This implies that all points on any two curves are separated by the same constant amount; hence, the curves must be parallel. Any departure from parallelism implies non-additivity, or a significant interaction. Thus, an interaction test is tantamount to a rejection criterion for additivity: if interaction exists, additivity is rejected; if it does not, additivity is retained.

These concepts can be illustrated with reference to the data from an earlier study in Iowa City, Iowa, and illustrate how it can be used to guide specification (Figure 4.3). The data in Figure 4.3 are from a 3 x 3 x 3 factorial design in which a number of respondents judged each of the 27 combinations several times. The attributes were fare (15, 30, and 45 cents), walking distance (1, 3, and 9 blocks), and

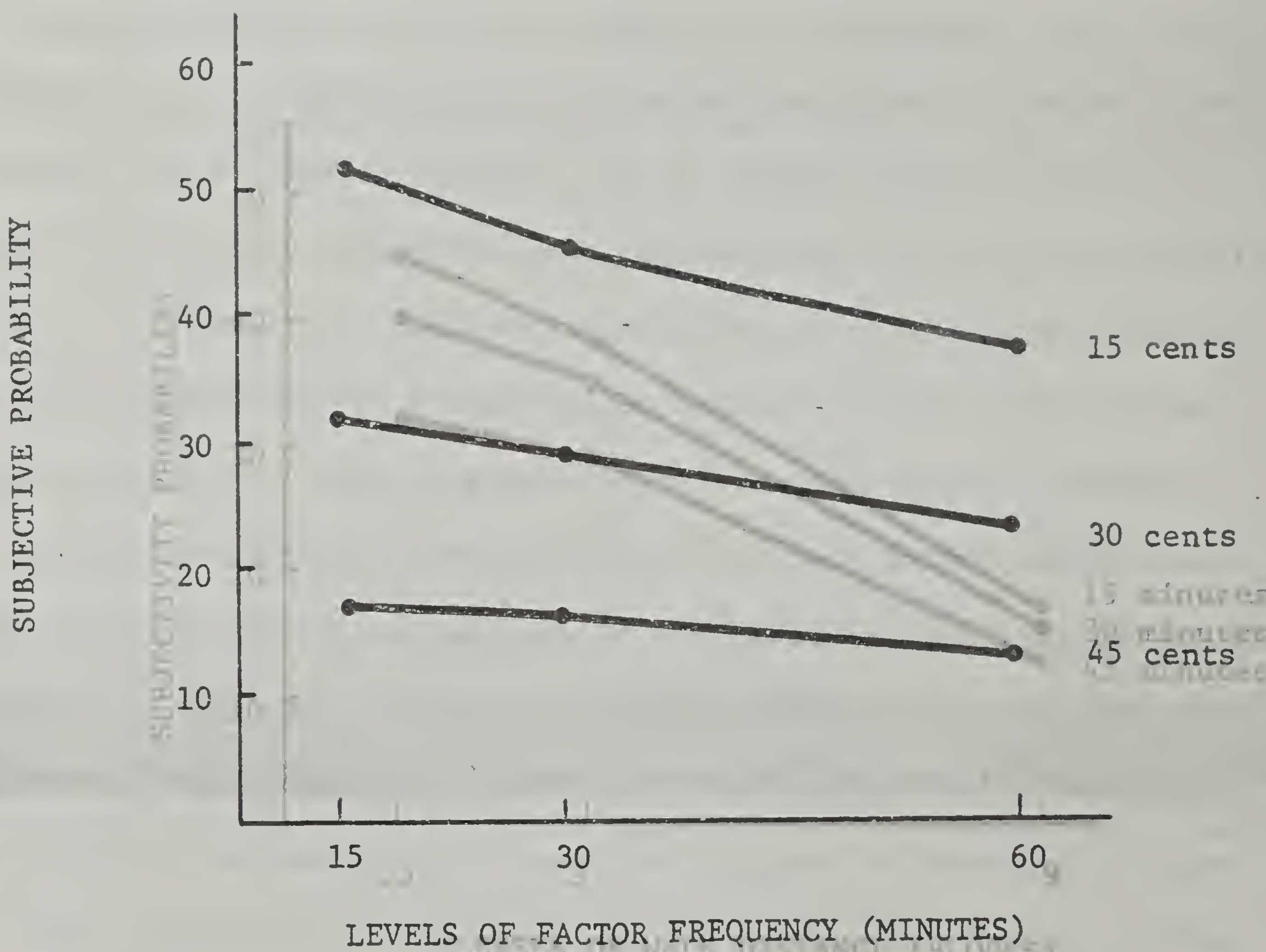


FIGURE 4.3a

Average Sample Response to Combinations of Frequency of Service and Fare, Holding Walking Constant

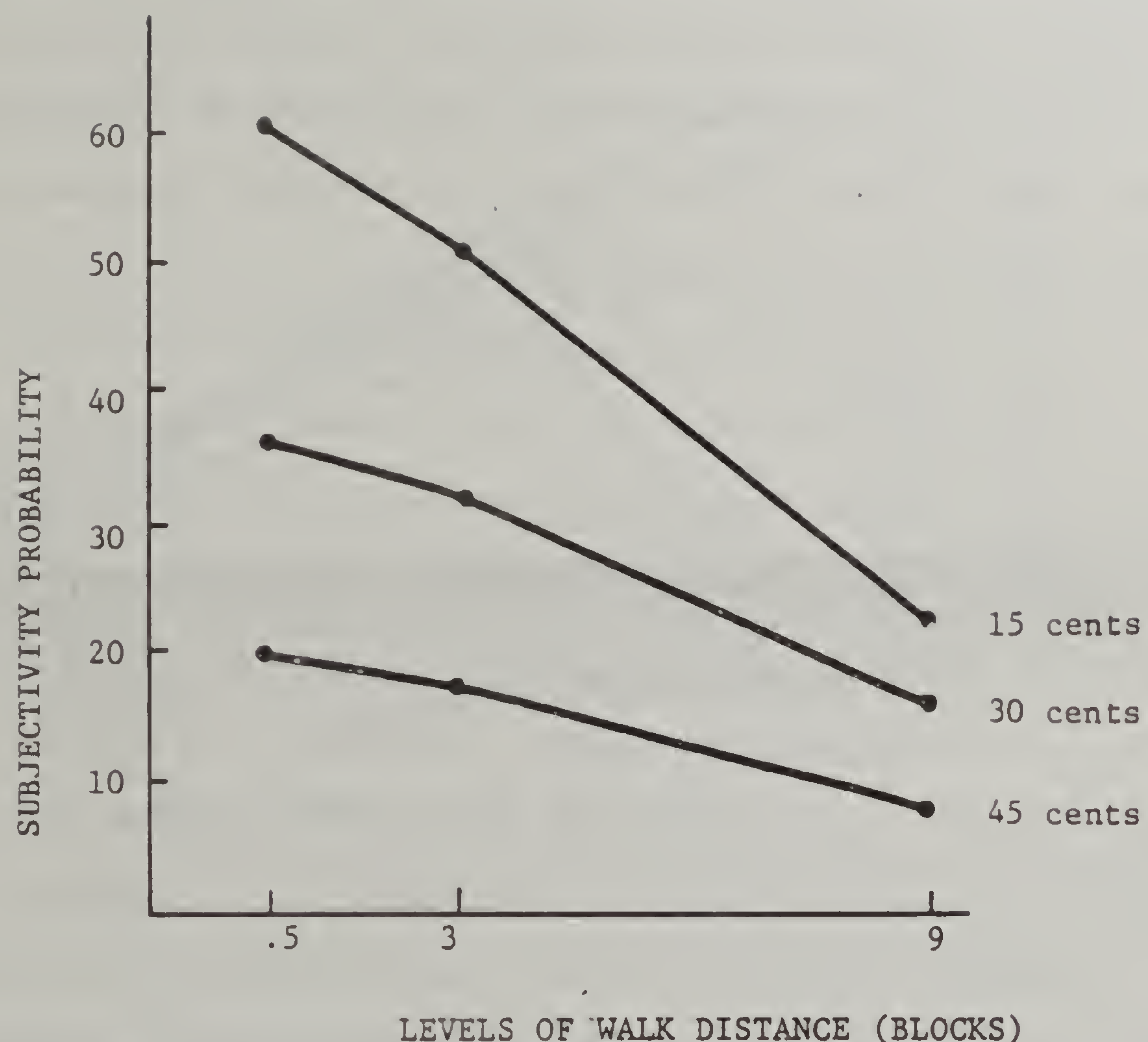


FIGURE 4.3b

Average Sample Response to Combinations of Fare And Walking Distance, Holding Service Constant

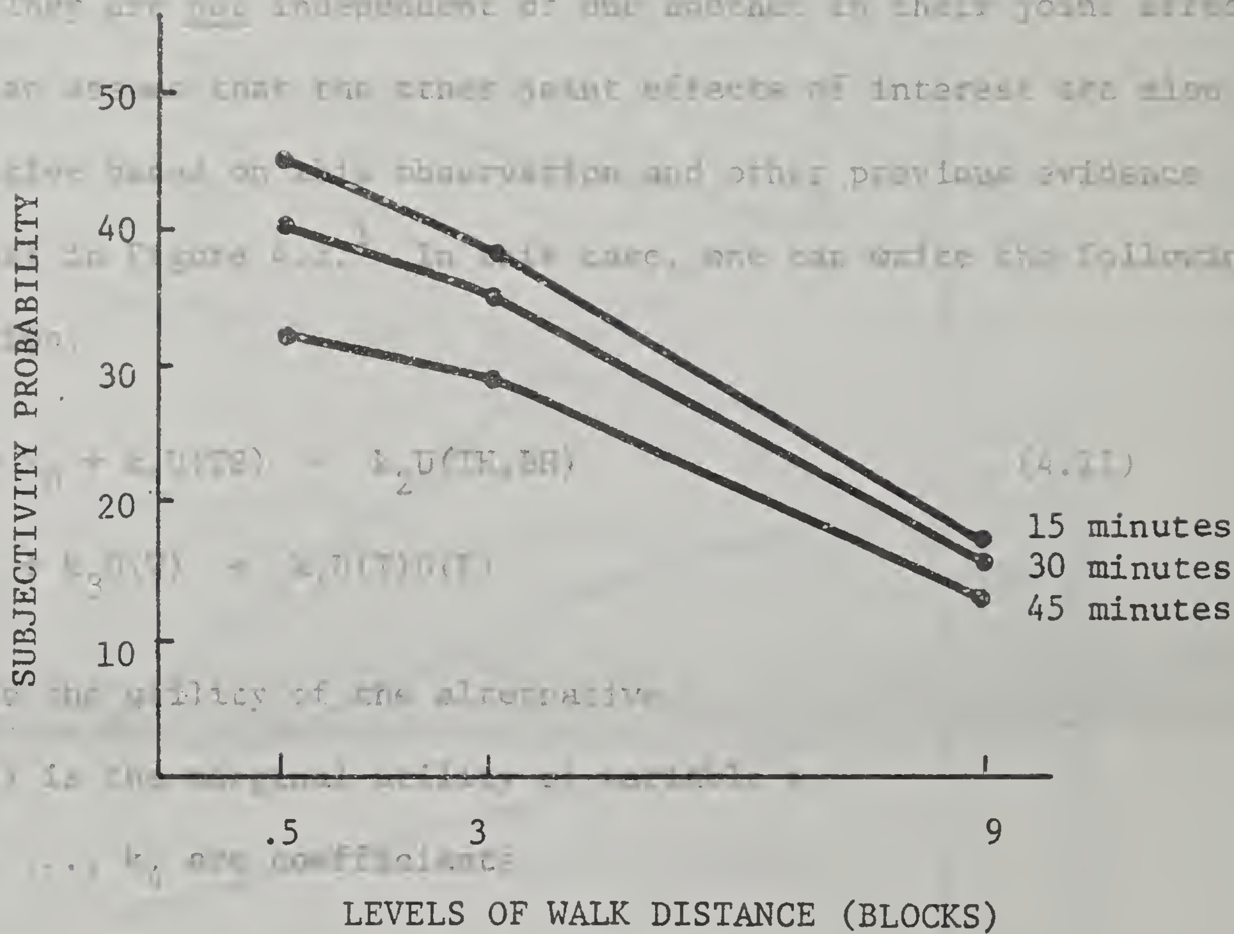


FIGURE 4.3c

<u>Average Sample Response to Combinations of Walking Distance And Frequency of Service, Holding Fare Constant</u>

headway (15, 30, and 60 minutes). As can be noted from Figure 4.3, each set of two-way interactions has the same form: when values are good, the curves diverge, as they become increasingly bad, the curves converge. This clearly implies that the joint effects of these attributes are non-additive. Indeed, the statistical tests of the interactions were all significant, confirming the visual information. In particular, this pattern of interaction curves implies a multiplicative value equation. As demonstrated in the appendix, multiplication implies that the amount of separation of the curves is directly proportional to the marginal value of the response at each level of the two attributes. This implies the pattern which is observed in Figure 4.3: increasing value of response to levels of one attribute should cause divergence in the curves of the second attribute. There are statistical tests for this expectation, which are discussed in the appendix. It should be clear, however, that the data curves in Figure 4.3a through 4.3c conform to this expectation. This means that users do not trade off service and cost at all levels of these variables. When one variable is at a poor level, improvements in other variables do not offset it, and the overall attractiveness of the alternative remains low. This interpretation may be quite relevant to the Xenia experience, as discussed in Chapter 5.

In the case of the Xenia data, these interactions cannot be reliably estimated because the factorial design is incomplete. It is possible, however, to estimate the joint effect of time and cost, holding all else constant, if one discounts the middle level of cost (50-cents)

which is always associated with 15-minute headways. This interaction is given in Table 4.7, and graphed in Figure 4.4. The results clearly indicate curves similar to those illustrated in Figure 4.3. In particular, one can note that if the cost is \$1, travel time difference is virtually irrelevant. The effect of travel time depends upon the level of fare. They are <u>not</u> independent of one another in their joint effects.

One can assume that the other joint effects of interest are also multiplicative based on this observation and other previous evidence such as that in Figure 4.3.[1] In this case, one can write the following specification:

$$U = k_0 + k_1U(TS) + k_2U(TH,BH) + k_3U(W) + k_4U(T)U(F) \qquad (4.11)$$

where

U is the utility of the alternative

U(x) is the marginal utility of variable x

$k_0, \ldots, k_4$ are coefficients

The overall response or value observed in cell i is an additive function of the marginal value for type of mode, headways within each mode, walking distance within the bus mode, and times and costs common to both modes. This specification is estimated from the values of the attribues in Table 4.6 using the following logic:

---

[1] This is only an assumption, not an inference, but it is supported by many previous studies.

TABLE 4.7

Time x Cost Interaction Means

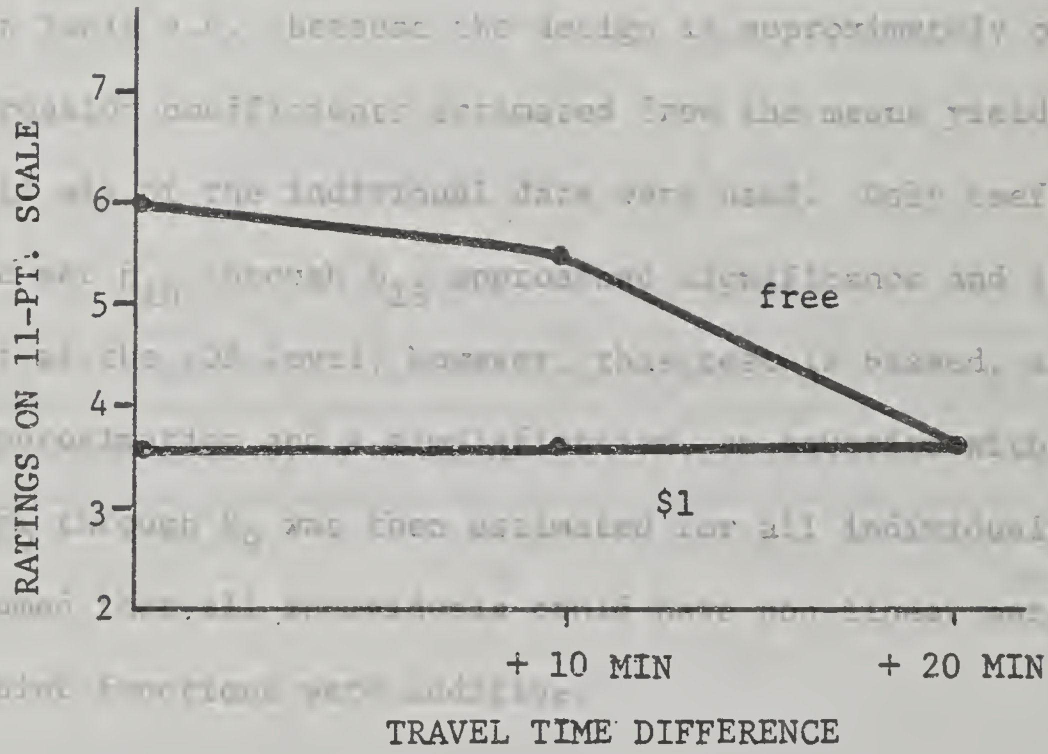
Work Trips

Transit Cost	Travel Time Difference (Transit - Auto)		
	Same	+ 10 min.	+ 20 min.
free	5.17	4.97	3.23
$1.00	3.28	3.18	2.98

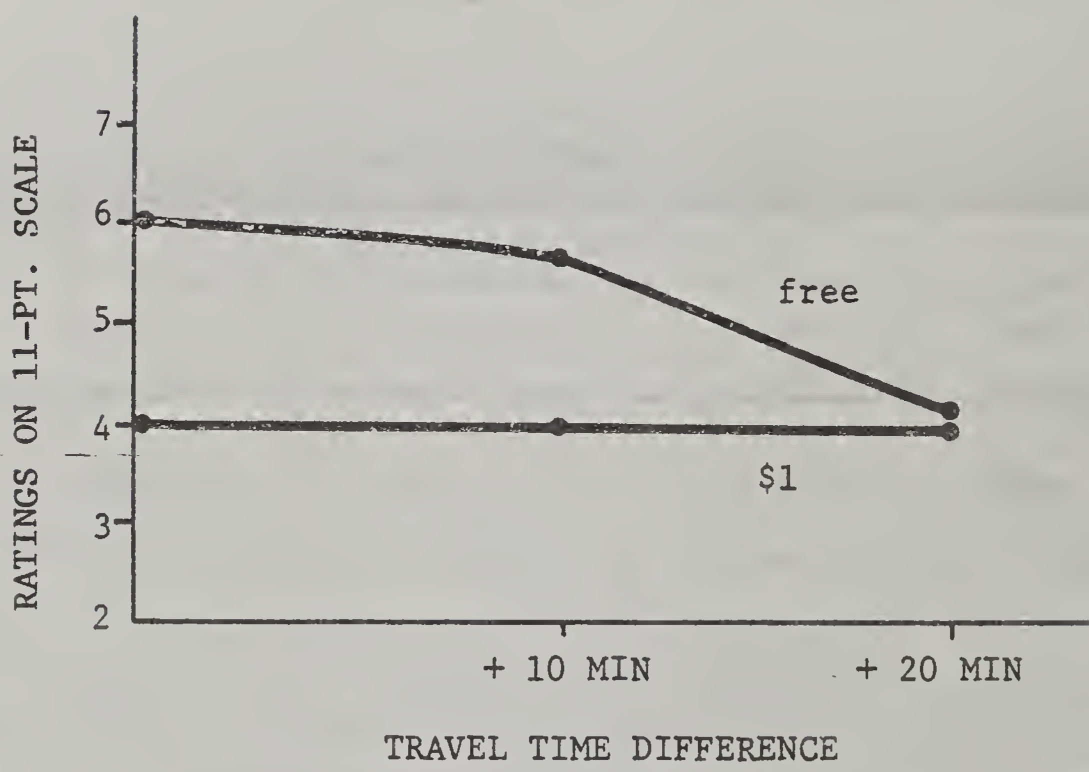
Shopping Trips

Transit Cost	Travel Time Difference (Transit - Auto)		
	Same	+ 10 min.	+ 20 min.
free	6.31	5.36	3.56
$1.00	3.68	3.52	3.48

Entries in table are mean rankings by respondents on an 11 point scale.



4.4a SHOPPING TRIP RESPONSE



4.4b WORK TRIP RESPONSE

FIGURE 4.4

Interaction Graphs of Time x Cost

$$U(TS) = a_1 + b_1(-1 \text{ if taxi; } +1 \text{ if bus}) \tag{4.12a}$$

$$U(BH) = a_2 + b_2(-1 \text{ if 15; } +1 \text{ if 30 min; 0 if taxi}) \tag{4.12b}$$

$$U(TH) = a_3 + b_3(-1 \text{ if on-demand; } +1 \text{ if call-ahead; 0 if bus}) \tag{4.12c}$$

$$U(W) = a_4 + b_4(-1 \text{ if 0, 0 if 3, 1 if 6}) + b_5(1 \text{ if 0, } -2 \text{ if 3, 1 if 6}) \tag{4.12d}$$

$$U(T) = a_5 + b_6(-1 \text{ if 0, 0 if 10, 1 if 20}) + b_7(1 \text{ if 0, } -2 \text{ if 10, 1 if 20}) \tag{4.12e}$$

$$U(C) = a_6 + b_8(-1 \text{ if 0, 0 if 50, 1 if 100}) + b_9(1 \text{ if 0, } -2 \text{ if 50, 1 if 100}) \tag{4.12f}$$

The coding for W, T, and C is the linear (b_4, b_6 and b_8) and quadratic (b_5, b_7 and b_9) coding from the method of orthogonal polynomials, discussed earlier and in Appendix B. Note that substitution of Equations 4.12a to 4.12f in Equation 4.11 gives an expanded form of 4.11:

$$U = \beta_0 + \beta_1\cdot(TS) + \beta_2\cdot(BH) + \beta_3\cdot(TH) + \beta_4\cdot(W) + \beta_5\cdot(W^2) + \beta_6\cdot(F) + \beta_7\cdot(F^2) + \beta_8\cdot(T) + \beta_9\cdot(T^2) + \beta_{10}\cdot(T\cdot F) + \beta_{11}\cdot(T\cdot F^2) + \beta_{12}\cdot(T^2\cdot F) + \beta_{13}\cdot(T^2\cdot F^2) + \varepsilon \tag{4.13}$$

It should be noted, however, that the quadratic term for cost (β_7) is confounded with headway and mode in the case of bus (β_2), so one can at best get an approximate test over the 18 combinations.

Equation 4.13 was estimated for the 18 cell means for the combinations in Table 4.6. Because the design is approximately orthogonal, the regression coefficients estimated from the means yield the same values as if all of the individual data were used. Only coefficient β_{10} from the set β_{10} through β_{13} approached significance and it was not significant at the .05 level; however, this test is biased, as noted above. As an approximation and a simplification, an equation with only coefficients β_0 through β_9 was then estimated for all individuals. Thus, it was assumed that all individuals could have non-linear marginals, but their joint functions were additive.

4.5 Forecasting From Individual Utility Models

One can estimate either the full or some reduced form of Equation 4.13 for each individual or at the aggregate level. To forecast choices one must assume that there is a rank-order relationship between the values that are predicted by the individual equations and the likelihoods of choice, i.e.:

$$P(A_j) = \mathrm{Max}[M(\hat{V}_{ji})] \tag{4.14}$$

where:

$P(A_j)$ is the probability of alternative j being selected by an individual i (perhaps individual i's long-term frequency of choice);

$\hat{V}_{ji}$ is the response or likelihood of use value that an individual's i Equation 4.13 will predict for alternative j; and

M is some monotonic (or rank-order) mapping.

Equation 4.14 implies that one must search through the V_j for each individual i and assign that individual to that alternative j with the highest V_j.

Thus, there are two approaches to forecasting:

1. Using a random sample of individuals, simulate their choice of mode for observed trips by substituting the levels or values of each attribute in each individual's equation for each trip for each trip purpose. Each individual is assigned to that mode alternative with the highest predicted value. Community-wide choice proportions are obtained

by calculating the proportions assigned to each mode in the sample and expanding to the population. Any sub-group can be similarly estimated.

2. Using the mean or average equations estimated over all individuals, repeat the simulation as in method 1. A single equation is used to represent each individual, rather than a separate equation unique to each individual. Both approaches are discussed in Chapter 5.

5. RESEARCH RESULTS

5.1 Individual Level Response Specifications

The initial analytical task was to estimate separate regression equations to explain the tradeoffs among level-of-service and cost attributes for each individual who completed the direct utility assessment experiment of the Home Interview Survey. Out of the 670 persons surveyed, 451 supplied sufficient data to permit separate equations to be derived. The results of this analysis are summarized in Table 5.1, which lists the average values of the calibrated coefficients, their standard deviations, and a tabulation of the number of observed t statistics in various categories ranging from not significant to highly significant. The average coefficient values are given for both raw attribute units (cents, minutes, blocks) and orthogonal polynomial units.[1] Standard deviations refer only to orthogonal polynomial units because the equations were estimated in those units. One can readily convert to raw attribute units through algebraic manipulations relating the orthogonal coding (see Equation 4.12) to the raw attribute values.

Results indicate that, relative to the size of the average coefficient, individuals were most variable regarding the quadratic terms and bus headway. The variance in quadratic terms is to be expected because quadratic shapes could vary widely among individuals;

[1]Orthogonal polynomial units refer to transforms of the attributes which permit linear and squared terms to be estimated. They are discussed in Chapter 4 and the Appendix.

TABLE 5.1

Descriptive Statistics for All Individual Coefficients
(Averaged Over Purpose)

Coefficient	Mean Raw***	Mean Orthogonal	Std. Dev.**	Categories: Frequencies of t Values* 1	2	3	4	5	6
Intercept	6.860	3.838	1.88						
Type of Service (TS)	0.456	0.228	0.74						
Bus Headway (BH)	0.039	0.291	1.17	22.0	14.2	17.1	7.3	22.4	17.1
Cab Headway (TH)	-1.298	-0.649	1.03						
Fare-Linear (F)	-0.015	-0.160	1.89	35.9	12.2	13.3	9.3	19.3	10.0
Fare-Quadratic (F^2)	-0.000193	-1.606	5.50						
Walk-Linear (W)	-0.077	-0.480	0.32	26.2	10.6	13.1	12.6	23.9	13.5
Walk-Quadratic (W^2)	***	0.003	0.28						
Time-Linear (T)	-0.0047	-0.030	0.08	39.0	16.4	13.7	9.5	14.0	7.3
Time-Quadratic (T^2)	***	-0.002	0.01						

*1=0 - 1.86 for t
2=1.861 - 2.306 for t
3=2.306 - 2.896 for t
4=2.896 - 3.355 for t
5=3.355 - 5.041 for t
6=5.041 + for t

Units	Raw	Orthogonal
TS	Taxi=0, bus=1	Taxi=-1, bus=1
BH	minutes	15 min.=-1, 30 min.=1
TH	on demand=0, call ahead=1	on demand=-1, call ahead=1
F, F^2	cents, cents^2	linear and quadratic coding (Eqn. 4.12)
W, W^2	minutes, minutes^2	linear and quadratic coding (Eqn. 4.12)
T, T^2	minutes, minutes^2	linear and quadratic coding (Eqn. 4.12)

**Std. Dev. refers only to the orthogonalized variables and not to the raw form of the coefficients.

***Essentially zero.

N = 451

2.306 is the t value at a 95 percent significance level for eight degrees of freedom.

the variation in bus headway coefficients is less interpretable, but indicates a wide range of reaction to that type of service/headway factor.

Also included in Table 5.1 are the percents of coefficients with various t values observed over the 451 respondents.[1] As indicated, 2.306 is the cutoff for significance at the 95 percent level; hence, it is interesting to note that many respondents had non-significant fare (48.1 percent) or time (56.4 percent) coefficients, while most had significant type of service/headway (63.8 percent) and walk distance (63.2 percent) coefficients. This finding supports commonly held notions about the aggregate "importance" of out-of-vehicle time effects (walk and headway/wait times) in travel demand data.

A more interesting and important analysis of these coefficients involves asking whether they are independent of one another. That is, if one observes a respondent with a significant or high t value for cost, is it also likely that this respondent has a high t value for time? This information can have important planning implications if it can be shown that the t values are dependent (related) because it would imply that individuals that are strongly influenced by one attribute are strongly influenced by one or more others as well. This would indicate that the evaluation of the system from the individual's perspective would depend on both or three or all four of the attributes. The hypothesis is that all are strongly interrelated so that a high t on one attribute should imply a high t on the remaining attributes.

[1] In a controlled experimental plan such as the Xenia design, t values reflect not only precision of estimate but also relative effect or significance.

In order to test this hypothesis, a multiple contingency or cross-classification analysis was performed on the individual t values using the classes in Table 5.1. Results indicated that the dependence hypothesis should be rejected in part: cost or fare was found to be <u>independent</u> of the remaining attributes; but the other three were all dependent. Thus, a high t value for walking also implies a high t value for travel time and for headway. All relationships were positive, indicating that all three jointly increase (or decrease). The finding that evaluations of cost are independent of evaluations of service is interesting and potentially important if found in future work; it implies that the other three attributes constitute the "level-of-service" component and that the influence of cost is independent of their influences. Hence, cost affects different individuals in different ways, which are explored in the following analyses of the individual coefficients.

5.1.1 Analysis of Individual Differences in Coefficients

The second research task was concerned with testing the hypothesis that differences in the regression coefficients of individual response equations are associated with differences that can be observed about the individuals: differences in age, sex, income, previous history of transit usage, auto ownership, etc. In order to evaluate this hypothesis, a multiple analysis of variance was performed. A multiple analysis of variance permits one to test the hypothesis that one or

more independent variables account for differences in two or more (multiple) dependent variables. In addition, this analytical technique allows one to examine the effects of the independent variables on <u>each</u> of the dependent variables separately as well as together.

In the present context interest centered on examining differences in the individual regression coefficients as a function of differences in interpersonal measures such as auto ownership, income, sex, age, previous history of transit usage and the like. In addition, interest focused on differences in individual weights as a function of these interpersonal differences. Weight refers to how much influence an attribute has on an individual's responses when evaluating the alternatives; the higher the weight, the more influence an individual accords an attribute in making judgments. Technically, one measures weight as the proportion of "explained variation" from the overall regression equation that can be attributed to variation in a particular attribute. Weights are therefore standardized so that a weight of 1.0 means that an individual considers that attribute to the exclusion of all others, while a weight of 0.0 means that a particular attribute is ignored. Intermediate weight values refer to intermediate influence and the sum of the attribute weights is always unity.

Thus, the two analyses are complementary: the analysis of the regression coefficients supplies information about variation in shape of individual functions as a function of variation in individual difference measures; the analysis of weights supplies information regarding variations in influence that are associated with variations in interpersonal variables.

The full list of interpersonal variables and a summary of results is given in Appendix D. (In Table D.1, any significant interpersonal difference effects are noted for both weights and regression coefficients. Also, one can examine overall or global effects of the interpersonal factors on the weights or coefficients taken as a whole by examining the "overall test" rows in Table D.1.)

Because there are many significant effects, attention will be confined to discussion of some of the most significant effects to illustrate the power of the procedure to detect important differences in traveller responses as related to differences among traveller characteristics. These results are given in Figure 5.1, which shows the results uncovered for selected effects. In Figure 5.1.a (parts 1 through 22), the vertical axis is the value of the regression coefficient for a particular attribute, while the horizontal axis is the value of the interpersonal difference factor. In Figure 5.1.b (parts 1 through 6), the vertical axis is the value of the weight coefficient, and the horizontal axis is the level of the individual difference factor. The interpretation of these results is as follows.

<u>Figure 5.1.a</u>

(a.1) This figure indicates that the average self-estimated probability (the intercept or grand mean) of using any of the 18 transit alternatives decreases with income, but not in a simple linear manner. The probability drops off rapidly after the first income category and decreases slowly thereafter.

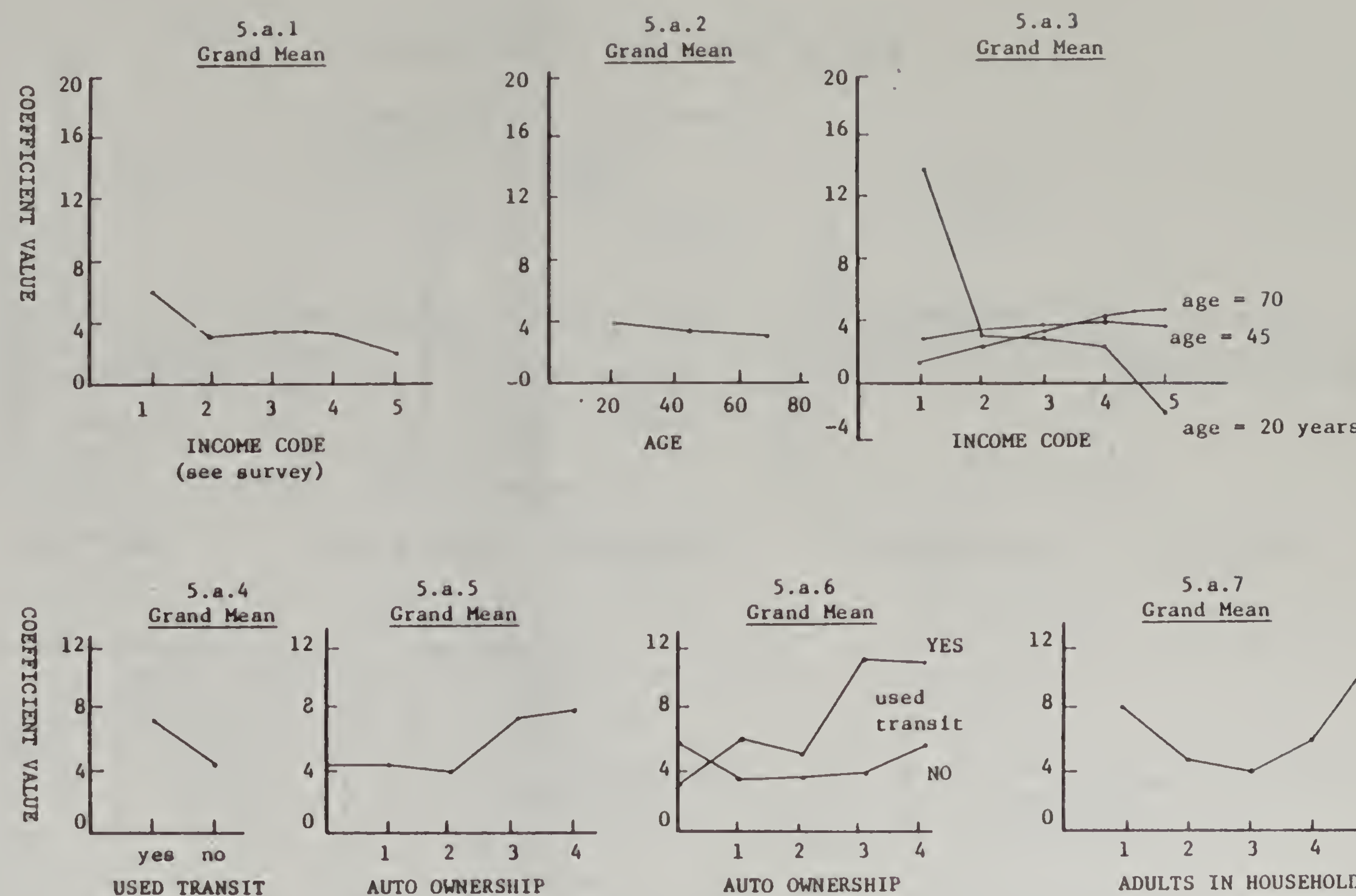


FIGURE 5.1

Results of Analysis of Interpersonal Effects

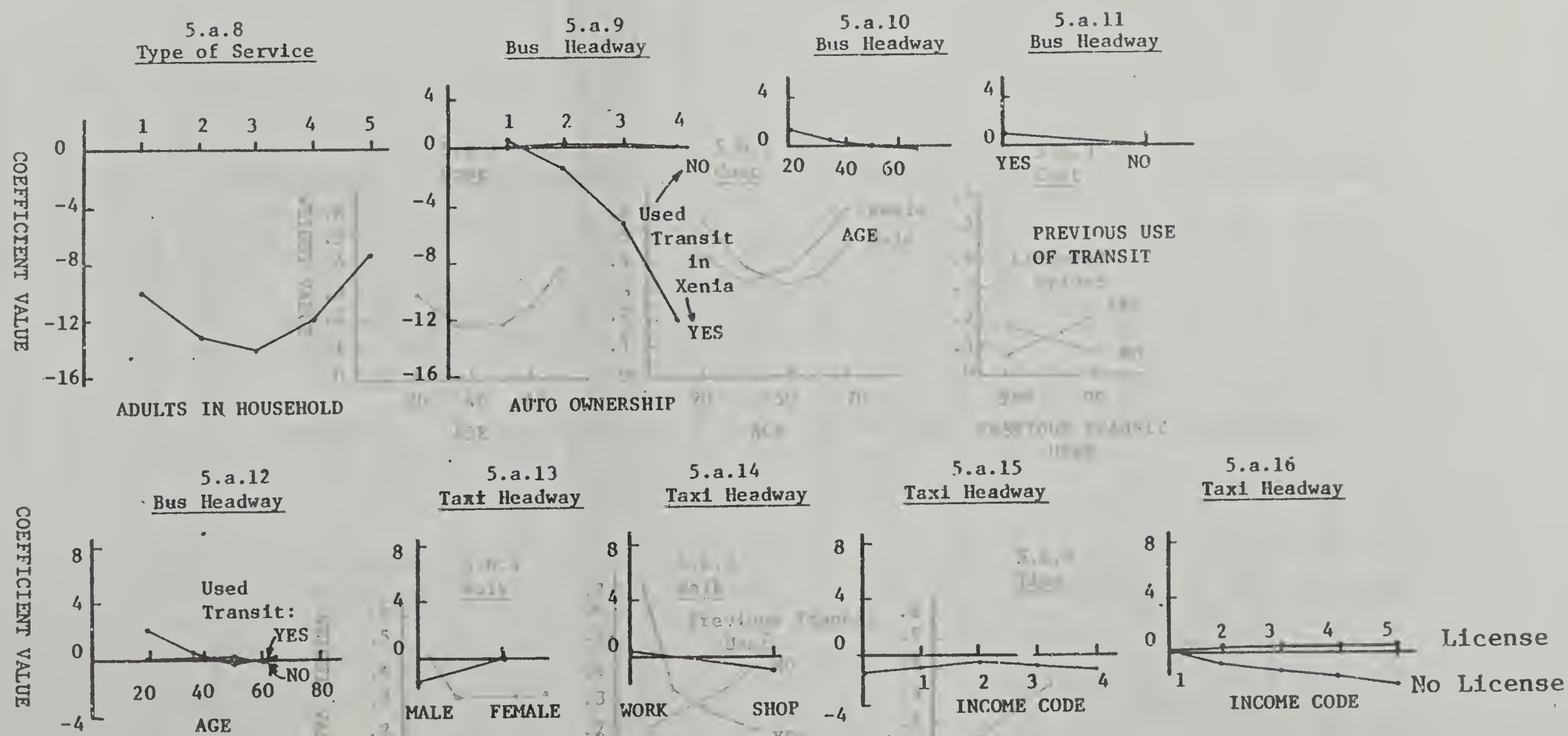


FIGURE 5.1 (continued)

Results of Analysis of Interpersonal Effects

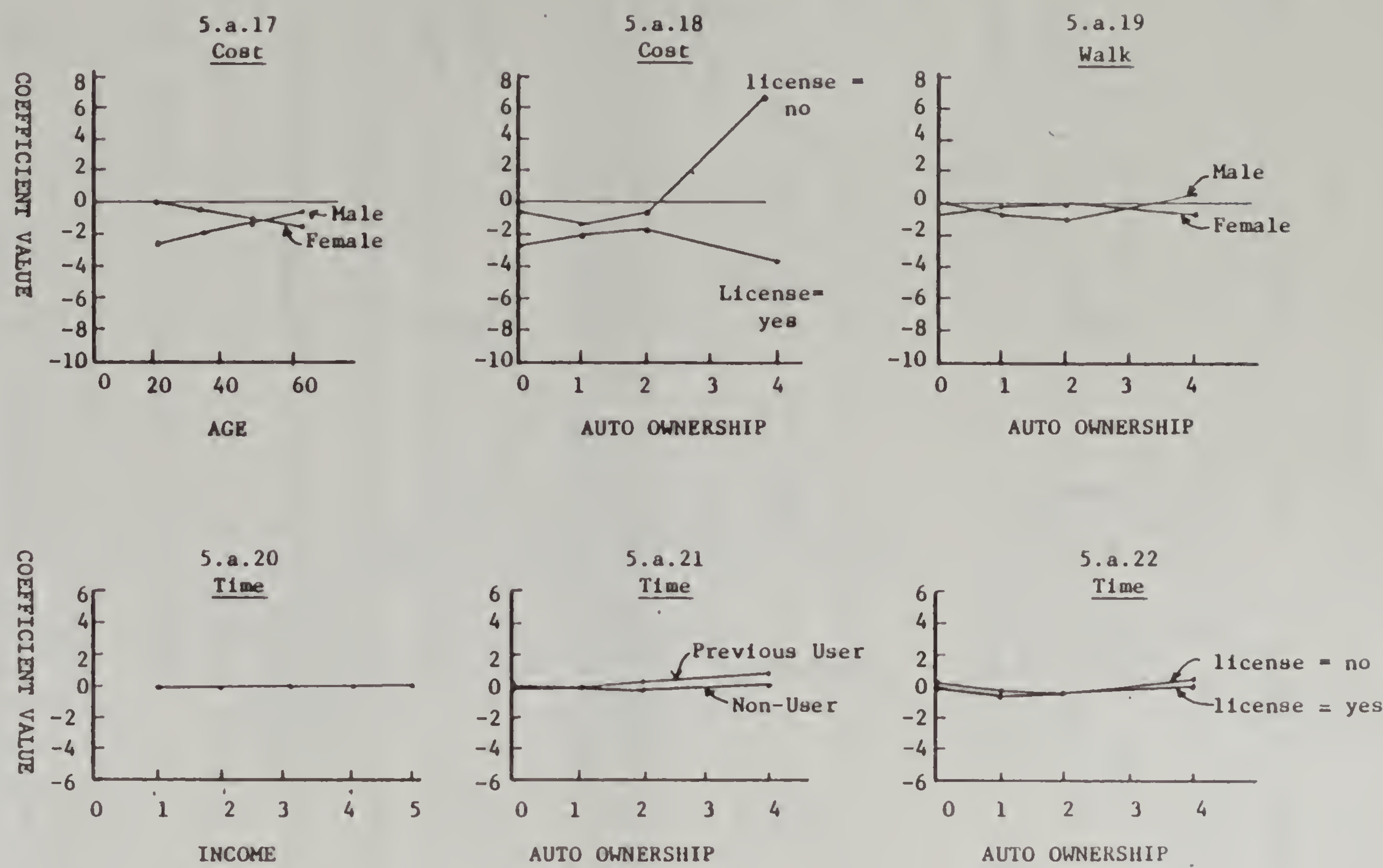


FIGURE 5.1 (continued)

<u>Results of Analysis of Interpersonal Effects</u>

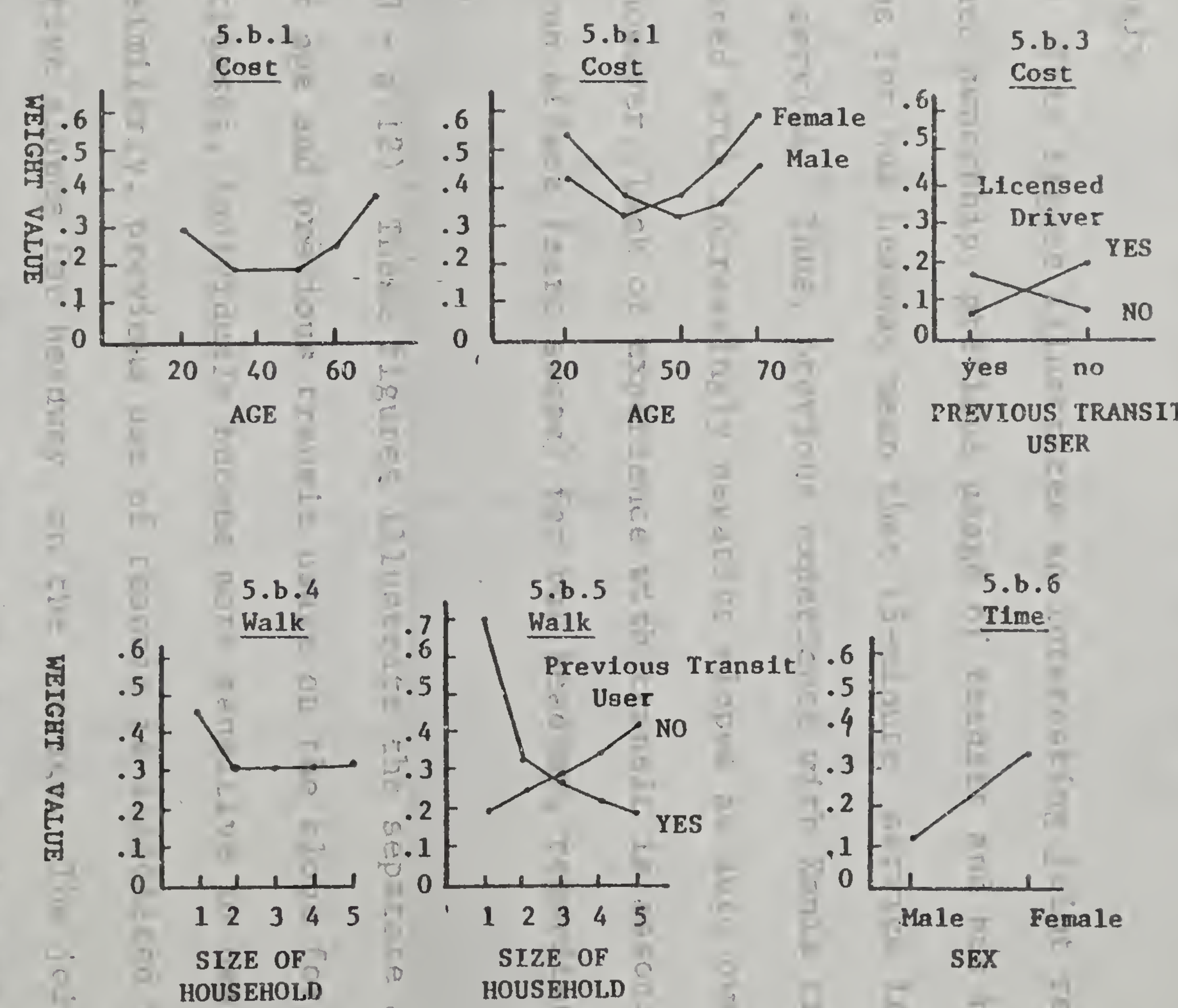


FIGURE 5.1 (continued)

Results of Analysis of Interpersonal Effects

(a.2) This figure indicates that the average self-estimated probability of use of the 18 alternatives decreases linearly with age.

(a.3) This figure shows the joint effects of income and age on the average self-estimated probability of use which differs significantly by both age and income. It appears that income effects are lessened by increasing age.

(a.4) This figure shows that previous experience with prior systems in Xenia significantly raises the average self-estimated probability of use.

(a.5) This figure shows that the average self-estimated probability of use at first decreases with ownership of up to two autos, then rapidly increases. The values for three and four autos, however, are based on very few observations or correlated with one of the other attributes in a manner not determinable from these data.

(a.6) This figure shows that there are significant differences in the average self-estimated probability of use of the 18 alternatives according to whether the individual has had previous experience with transit. No previous experience with Xenia public transportation results in a lower curve except for "no autos". As in Figure 5.a.5, the three and four auto observations are limited.

(a.7) This figure shows that the average self-estimated probability of use of the 18 systems is a U-shaped function of the number of adults in the household. At first, probability decreases until one reaches three adults and then rapidly climbs again. There are few four- and five-adult households in the sample, however.

(a.8) Similar to Figure 5.1.7, this figure shows that the value for type of service is a U-shaped function of the number of adults in the household. Negative values favor bus and positive values favor taxi. Thus, bus is favored regardless of household size over the range illustrated; however, very small and very large households prefer bus less strongly.

(a.9) This figure illustrates an interesting joint relationship between auto ownership, previous usage of transit and bus headway. Negative slopes for bus headway mean that 15-minute service is preferred to 30-minute service. Thus, previous experience with Xenia transit service is associated with increasingly negative slopes as auto ownership increases; however, lack of experience with transit is associated with virtually no effect (zero slope) for bus headway, regardless of auto onwership.

(a.10 - a.12) These figures illustrate the separate and joint effects of age and previous transit usage on the slope for bus headway. As age increases, individuals become more sensitive to headway on the average; similarly, previous use of transit is associated with slightly less negative slopes for headway on the average. The joint effect of age and previous usage (a.12) indicates that most of the effect is confined to previous transit users--the slope is approximately zero for those who have never used Xenia public transportation.

(a.13) This figure indicates that there is a significant difference in slope for taxi headway by sex. Negative taxi headway values are associated with preferences for on-demand as opposed to call-ahead

service. Thus, males appear to be more sensitive to this difference than females and prefer on-demand service; indeed, females appear indifferent on the average because their value is zero.

(a.14) This figure suggests that the taxi headway slope differs significantly by trip purpose. On-demand service is preferred for shopping trips on the average; work trips are largely indifferent, with a slight tendency toward call-ahead service.

(a.15) This figure illustrates taxi headway slope differences as a function of income. Lower and upper incomes appear to be most sensitive to the difference in call-ahead and on-demand.

(a.16) This figure shows that the slope for taxi headway differs significantly by both income and possession of a driver's licence. For licensed drivers, as income increases, there is little effect on slope; and, in fact, slope is approximately zero. In the case of unlicensed individuals, as income increases, slopes for taxi headway decrease indicating increasing dislike for call-ahead service.

(a.17) This figure demonstrates contrasting age and sex effects on the slope for cost. As females age, their slopes for cost increase on the average indicating increasing sensitivity to cost. On the other hand, as males get older, cost slopes increase indicating less sensitivity to cost on the average.

(a.18) This figure displays the joint effect of auto ownership and possession of a driver's license on the slope for cost. As auto ownership increases, if the respondent is a licensed driver, cost slopes at

first increase than decrease after two autos. If the respondent is unlicensed, the cost slope decreases from zero to one auto and then rapidly increases, indicating that cost is ignored.

(a.19) This figure suggests that females become less sensitive to walking distance up to ownership of three autos, while males become more sensitive up to three autos. Again, observations of four or more autos are probably limited; hence, these points should be interpreted with caution.

(a.20 - a.22) These figures illustrate significant differences in the time slopes by income, auto ownership, possession of a driver's license and previous transit usage. By inspection, these effects appear minor and the "significance" of these results is probably due more to low variance in the slopes of these groups (or high precision of estimate) than to a real "effect." In essence, the graphs show that these groups have virtually zero slopes for time. Perhaps of most interest is the finding that the slope for time is largely independent of income (a.20).

Figure 5.b.

The remaining figures (b.1 - b.9) refer to the "weight" or amount of effect of each attribute.

(b.1) This figure shows that younger and older individuals place most weight on cost on the average. However, figure b.2 indicates that this U-shaped relationship differs by sex. Younger males place more weight on cost than females, but older females place more weight on cost than males.

(b.3) This figure indicates that weight differs significantly by both previous use of transit and possession of a driver's license. Respondents without a driver's license and with a previous history of transit usage place more weight on cost as do licensed drivers with no previous transit usage. Previous transit usage and a license, however, are associated with lower weight, as is no license and no experience with transit.

(b.4) This figure shows that as household size increases from one to two or more, the weight for walking distance drops and then remains constant. Thus, one-person households place more weight on walking distance. If, however, one examines the joint effect of household size and transit usage (b.5), it is clear that previous transit users weight walking less as household size increases. On the other hand, respondents with no transit experience, weight walking more as household size increases.

(b.6) This figure indicates that females place considerably more weight on travel time differences than males in responding to the 18 alternatives. This is a function of trip purpose with a greater proportion of females' trips being for non-work purposes than for males.

These selected results indicate the power of the direct value assessment techniques to detect important differences in traveller groups' responses to mode choice attributes. Because separate coefficients can be estimated for separate individuals, the analyses described above can be performed. Although all of these analyses could have been performed by means of a single expanded regression analysis in estimating

the utility function with socioeconomic variables, the number of possible terms to be investigated makes this an unattractive alternative. For example, each separate regression analysis involved 117 terms; thus a full regression analysis would require 1170 terms (10 coefficients times 117 terms), currently practically impossible to solve on many (if not all) computers. The strategy adopted in this research task, therefore, is recommended where the number of possible terms of interest is large. The results of this analysis, therefore, clearly indicate the power of the technique to examine interpersonal differences in responses to proposed service and pricing changes. Likewise, groups likely to be significantly impacted or which are of particular policy interest can be singled out for analysis.

5.1.2 Individual Forecasting System Results

The final research task which involves the analysis of individual response functions is the construction and testing of an individual forecasting system. This is an important and necessary step to validate the method. If the system appears to perform well with historical data, it can be used to develop elasticity estimates and to evaluate demonstration projects both before <u>and</u> after their implementation. Thus, if the system validates well, it can be used to compute measures for service level and cost, which can extend the analysis in the primary evaluation report[1] and assist in reaching conclusions regarding service and cost tradeoffs.

[1] The Xenia, Ohio Model Transit Service Demonstration Project: Transit and Paratransit Services for a Small Urban Area.

The individual level forecasting system consists of two components: (1) a set of individual coefficients for 451 of 670 respondents who completed the experiment in the home interview survey; and (2) a set of engineering or physical measures for type of service and headway level, cost of service, walking distance to service and travel time difference of transit minus auto. These measures are computed for each intra-Xenia home-based work, and home-based shop trip observed in the travel pattern section of the home interview survey. Hence, for each intra-Xenia trip, each of the levels of the four attributes were measured using available data. These measures were then substituted into each individual's set of coefficients and an expected "likelihood of use" value can be generated for each alternative mode. For example, for the 1977 paratransit system, one can generate attribute measures for auto, taxi on demand and taxi call-ahead service by measuring network times, transit wait times, etc. These measures were substituted into an individual's set of coefficients and an expected value derived for each of these three alternatives.

Since "auto" is the base alternative in the Xenia study against which all the transit options are compared, it is necessary to establish a value for auto to use as the basis for comparison. This is accomplished by subtracting the intercept (or grand mean) from the top of the response scale (the value "11") plus one.[1] This is done because the intercept has the interpretation that it is the "average likelihood of using" any of the 18 alternative transit systems. Thus one minus this

[1] The value "1" is added because the base of the response scale is 1, not 0.

average probability yields the average probability of using some mode other than the 18 transit alternatives. Because virtually all Xenia respondents have automobiles, it is reasonable to assume that this adjusted figure represents the auto term. Thus, if the top of the response scale were 11, and the grand mean of the transit alternatives were 4, the auto value would be 8 (11 - 4 + 1).

In order to forecast, it is necessary to assume that the individual is most likely to select that alternative which receives the highest predicted value computed from the individual's set of coefficients. Then, by counting how many individuals are predicted to select each alternative, one can generate aggregate mode shares. The results of the application of this procedure to the Xenia home interview data are given in Table 5.2. This table displays the results of applying the forecasting procedure to develop mode shares for the first fixed-route bus system (1974), the second fixed-route bus system (1975), the third fixed-route bus system (1975), the 1976 shared-ride taxi system, and the 1977 paratransit system. All these options are described in Chapter 2.

Table 5.2 includes four options for computing the cost of auto and the travel time for transit. The intent of the experiment had been for respondents to consider only transit cost explicitly, as it was believed that short auto trips in a small city have a low perceived cost. Also, it was intended for the headway variable to include all wait time considerations, with the travel time variable reflecting only in-vehicle time differences between auto and transit. However, because it was possible that respondents viewed these attributes in a

TABLE 5.2

Results of Individual Forecasting System

	Transit Mode Share			
	No Explicit Auto Cost, Transit Travel Time Exclusive of Wait Time	No Explicit Auto Cost, Transit Travel Time Inclusive of Wait Time	Explicit Auto Cost, Transit Travel Time Exclusive of Wait Time	Explicit Auto Cost, Transit Travel Time Inclusive of Wait Time
1977 Work	.06	.06	.05	.06
1977 Shop	.10	.10	.12	.11
1976 Work	.08	.11	.11	.08
1976 Shop	.11	.14	.14	.11
1975 (3)* Work	.09	.09	.10	.06
1975 (3) Shop	.10	.10	.09	.07
1975 (2) Work	.08	.06	.08	.05
1975 (2) Shop	.08	.08	.08	.07
1974 (1) Work	.10	.06	.09	.04
1974 (1) Shop	.08	.06	.07	.05

*Numbers in parentheses refers to the fixed route system, for example, (3) refers to fixed route system three.

different way than anticipated, alternative assumptions were also tested; namely, that the cost of auto trips was perceived at near 10 cents per mile, and that the transit travel time variable included both wait and in-vehicle time. However, there does not seem to be any significant systematic effect from these different measures observable in Table 5.2.

Because there seems to be no systematic trend in the data, the results of the base option are graphed against the observed mode choice data and displayed in Figure 5.2. This figure reveals a potentially non-linear relationship between the forecasting results for the work trip and the observed Xenia work mode choices. A similar relationship for shopping trips is not available because of unavailability of an accurate estimate of shopping trips as a proportion of total non-work travel. The relationship is consistent with a number of similar results reported in previous applications of this technique. The interpretation of this result is that a simple rank-order transformation exists to transform predicted into observed values. Moreover, this relationship implies that the forecasting system is predicting results consistent with observed behavior in Xenia. Thus the results of the analysis of the individual coefficients can be tentatively accepted as representative of traveller responses during the Xenia demonstration. A stronger test of this assertion would be to use the experimentally derived utilities as the independent variables in, say, a disaggregate logit formulation to derive scale factors or other corrections. If these

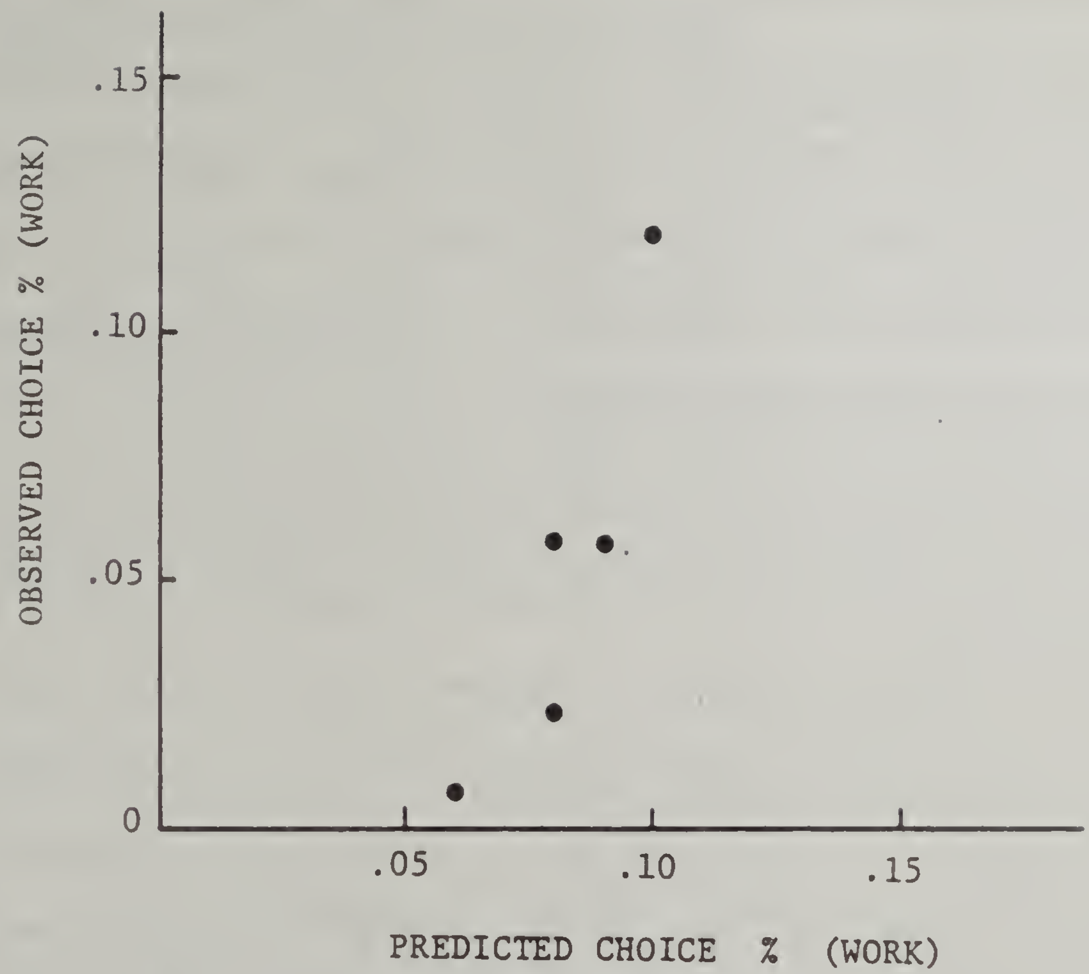


FIGURE 5.2

Observed Versus Predicted Work Mode Split

parameters were reasonable, a validation exercise could then be done to assess the adjusted model's validity. If successful, the results of this kind of analysis can be used _a priori_ to guide demonstration projects and detect differences in potential responses and impacts for different groups of individuals as well as to evaluate the same factors during and after demonstrations.

5.2 Aggregate Level Response Specifications

The major effort in this portion of the research was to develop alternative aggregate tradeoff expressions for the data derived from the home interview survey. In order to accomplish this task objective, the data were analyzed in two ways.

(1) The average "likelihood of use" value observed over all respondents was calculated for each of the 18 alternative transit systems. These 18 averages were employed as the "expected response" of the sample to each alternative and a regression equation was fit to these 18 data points in exactly the same manner as done for the individual respondents (see Section 5.1 and Equation 4.11).[1] Separate equations were estimated for work and shop trip purposes.

(2) The number of responses observed to be greater than or equal to category seven (7) on the response scale was calculated for each of the 18 alternatives. This procedure was used because category seven represents a self-estimated "likelihood of using" an alternative of over 50 percent. Hence, the total of these responses for an alternative divided by the total possible responses for that alternative can be interpreted as an estimated of the relative proportion of "regular users" of an alternative. When normalized by dividing the number of responses of seven or greater over <u>all</u> alternatives, this yields the

---

[1]The reason that one can use the overall averages for each of the 18 alternatives is because it can be shown that if a balanced sampling plan was used to collect the observations, the coefficient estimates will be identical to these estimated from the entire set of individual data points. Because the Xenia sampling plan is almost balanced, this property is expected to be approximately true. A considerable savings in computer processing is therefore realized using this approach.

relative proportion of "regular users" of alternative i compared to all other "regular users" of all other alternatives. Separate regression equations for work and shop (see Section 5.1 and Equation 4.11) were fit to these 18 adjusted cell proportions.

The data used to generate the regression equations and the orthogonal coding values of the four attributes (headway and type-of-service, cost, walking distance and travel time differences) are listed in Table 5.2. The final estimated specifications of these equations are given below:

$$V_i^w = 3.5089 + 0.3(TS_i) + 0.2(BH_i) - .65(TH_i) - 1.33(F_i) - 1.22(F_i^2) - 0.32(W_i) - 0.01(W_i^2) - 0.05(T_i) - 0.0013(T_i^2), \tag{5.1a}$$

$$V_i^s = 3.832 + 0.16(TS_i) + 0.44(BH_i) - 0.5(TH_i) - 1.52(F_i) - 1.5(F_i^2) - 0.43(W_i) - 0.018(W_i^2) - 0.065(T_i) - 0.0026(T_i^2), \tag{5.1b}$$

$$P_i^w = 0.175 + 0.23(TS_i) + .024(BH_i) - .84(TH_i) - .142(F_i) - .105(F_i^2) - .032(W_i) + .006(W_i^2) - .004(T_i) - .00034(T_i^2), \tag{5.2a}$$

$$P_i^s = 0.176 + .014(TS_i) + .063(BH_i) - .102(TH_i) - .148(F_i) \; 0 \; .165(F_i^2), - .037(W_i) - .00062(W_i^2) - .006(T_i) - .0001(T_i^2), \tag{5.2b}$$

where i is the number of alternatives (i = 1 - 18);

V_i^w and V_i^s are the expected average response values for work and shop, respectively;

P_i^w and P_i^s are the unadjusted predicted proportion of regular users (7 or greater) for work and shop, respectively;

TS_i is a dummy variable representing type of service (-1 if taxi; +1 if bus);

BH_i is a dummy variable representing headway nested within bus service (-1 if every 15 minutes, +1 if every 30 minutes; 0 if taxi service);

TH_i is a dummy variable representing headway nested within taxi service (-1 if on demand, +1 if call ahead, 0 if bus);

F_i and F_i^2 are fare or cost of service and the square of cost, respectively;

W_i and W_i^2 are walking distance to transit stop and the square of walking distance, respectively; and

T_i and T_i^2 are travel time difference and its square, respectively.

F_i, F_i^2, W_i^2, T_i, T_i^2 are coded using the orthogonal polynomials.

Equations 5.1a - 5.2b indicate that on the average, the Xenia sample preferred buses to taxis (positive coefficient for type of service); preferred 30-minute headway to 15-minute headway (positive coefficient for headway), although this latter observation may be due to confounding of 15-minute headway (see Section 4.3 and Table 4.6); and prefer lower costs, shorter walks and lower travel time differences. These relationships are displayed in Figure 5.3 for cost, walk and travel time; type of service and headway are omitted in the graphs because they are dummy variables. The graphs in Figure 5.3 are derived directly from the equations listed above. These graphs represent the marginal response values which are the expected values of the respective aggregate response measures for a single attribute, holding

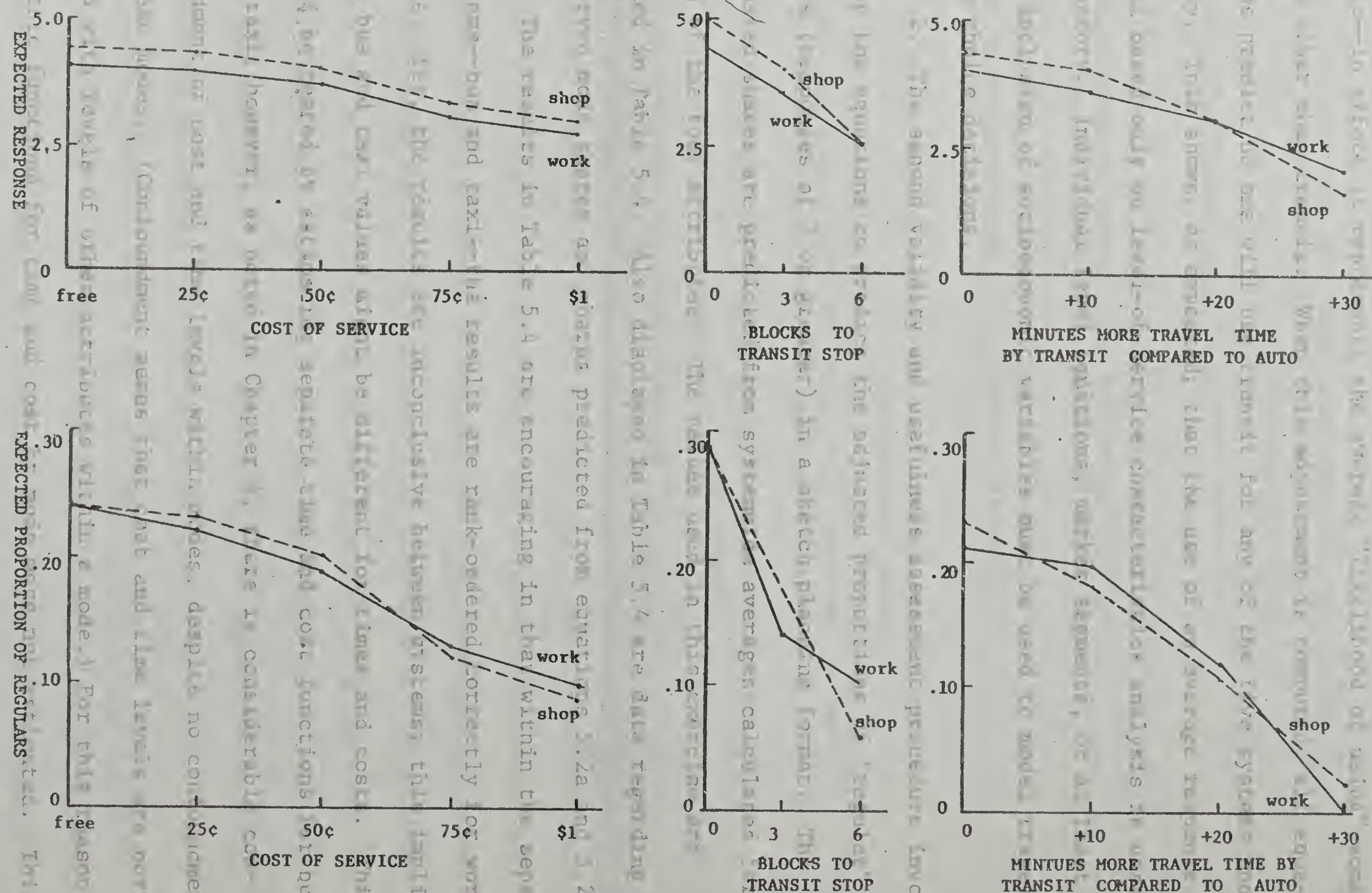


FIGURE 5.3

Summary of Aggregate Model Responses

other attribute levels constant. If the tradeoff process were strictly additive (and Figure 4.4 suggests it is not), then one could interpret these graphs as the marginal change in the aggregate response value as one changes the levels of a particular attribute, while holding all other attributes at their average value.[1]

The validity and usefulness of these equations may be assessed in two ways:

1. One can assume that all individuals share these common specifications and then use them to forecast choices by systematically applying them to the trip data for all intra-Xenia trips in exactly the same manner as for the individual forecasting system. For example, to forecast mode shares for 1977, one substitutes values for taxi service and headway, cost of taxi, travel time difference and walk distance for each observed trip into the appropriate equation to generate expected values for call-ahead, on-demand and auto mode use. As with the individual forecasting system, the individual is assigned to that mode with the highest predicted value.

Auto mode is represented by taking the top category value, adding one, and subtracting the grand mean (12 minus the overall average or intercept term). Auto equals the difference between the average "likelihood of using" transit and the adjusted top of the response

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[1] Average values were zero for all dummy variates, 50 cents for cost; three blocks for walking distance and 10 minutes longer by transit for travel time difference.

scale--in effect it represents the average "likelihood of using" some mode other than transit. When this adjustment is computed, all equations predict no one will use transit for any of the five systems under study. This shows, as expected, that the use of an average response model based only on level-of-service characteristics analysis is unsatisfactory. Individual level equations, market segments, or at least the inclusion of socioeconomic variables must be used to model travel mode choice decisions.

2. The second validity and usefulness assessment procedure involves using the equations to predict the adjusted proportions of "regular" users (responses of 7 or greater) in a sketch planning format. The adjusted shares are predicted from systemwide averages calculated for each of the four attributes. The values used in this exercise are listed in Table 5.4. Also displayed in Table 5.4 are data regarding observed mode shares and shares predicted from equations 5.2a and 5.2b.

The results in Table 5.4 are encouraging in that within the separate systems--bus and taxi--the results are rank-ordered correctly for work trips. Yet, the results are inconclusive between systems; this implies that bus and taxi values might be different for times and costs. This could be tested by estimating separate time and cost functions for bus and taxi; however, as noted in Chapter 4, there is considerable confoundment of cost and time levels within modes, despite no confoundment between modes. (Confoundment means that cost and time levels are correlated with levels of other attributes within a mode.) For this reason, separate functions for time and cost by mode were not estimated. This is a simple matter to correct in future applications by insuring that

TABLE 5.3

Aggregate Sketch Planning Results

Year and System	Headway	Cost of Service	Blocks to Stop**	Travel Time Difference***	Observed Work Share	Predicted Work Share	Observed Shop Share	Predicted Shop Share
1977 Variable Fare Taxi	Peak Off-peak* CA CA OD OD	Peak Off-peak 75¢ 50¢ $1 $1	0	3.0	1.02%	5.54%	NA	7.55%
1976 Fixed Fare Taxi	CA OD	50¢ 50¢	0	3.0	2.07%	7.38%	NA	9.36%
1975 Mixed Route Bus #3	Every 30 Minutes	25¢	3.14	5.72	5.21%	6.60%	NA	7.16%
1975 Fixed Route Bus #2	Every 30 Minutes	25¢	2.37	5.05	5.35%	7.30%	NA	9.46%
1974 Fixed Route Bus #1	Every 30 Minutes	free	1.85	3.52	11.9%	9.37%	NA	9.97%

*CA stands for Call-Ahead Service; OD, for On-Demand Service.

**This column refers to the total blocks one must walk to and from system. For 1975 and 1974 systems, these are the calculated averages in the final data set.

***This column refers to transit minus auto, constant for 1976-1977 and calculated as system averages for 1974-1975 systems, in minutes.

future sampling plans permit one to derive separate estimates for attributes within modes. Thus, the observation that bus and taxi tradeoffs may be different must await the correction suggested above to determine its validity.[1]

Note that the results in Table 5.4 are also consistent with the positive and negative changes in patronage observed during the demonstration. Thus, the basic pattern of changes is captured by both the aggregate and individual modelling effort. Another way of assessing validity is to examine the elasticity values which the aggregate forecasts yield and compare these with observed elasticities from the demonstration.

These elasticities may be computed directly from the graphical data in Figure 5.3. For example, arc elasticities may be computed for each attribute.[2] Using the data from Figure 5.3, the arc elasticity for cost can be computed for each system fare change. These values can be compared with the elasticities calculated from the observed patronage variation collected during the demonstration. This comparison is summarized in Table 5.5. As can be noted in Table 5.5, the elasticities for bus and taxi systems agree with the rank-order pattern of observed

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[1] Work currently under contract from the DOT Program of University Research is being conducted at the University of Iowa to answer this and a number of other questions stemming from this research project and related work. Thus, some resolution of these issues should soon be available.

[2] Arc Elasticity is computed using the formula $N = \frac{-(V_1-V_2)}{(A_1-A_2)} \cdot \frac{A_1+A_2}{V_1+V_2}$ where V is the observed or predicted response value and A is the attribute value.

TABLE 5.4

Comparison of Model Forecasted Elasticities with Observed Xenia Values

Fare Change		Observed in Xenia *	Calculated From Survey Results
From	To		
free	25¢	-.51	-.04
25¢	50¢	-1.18**	-.86
50¢	75¢/$1	-.74	-.94

All elasticities reported are arc elasticities

* Unadjusted for seasonal variation or damaged auto replacement.

**Upper bound; likely to be somewhat less.

system results. As with Table 5.4, however, it appears that bus and taxi values may be different. Again, it can be seen that the aggregate forecast data yield results which correspond in rank order to those calculated from observed changes in behavior during the demonstration period.

It is important to note that it is not possible to account for differences in choice behavior due to seasonal variation or to replacement of damaged or destroyed vehicles in the observed Xenia data. Also, a very large proportion of early fixed-route ridership was school-age children, who were not included in the home interview survey, and for whom a 25-cent fare might be a significant deterrent to use. Thus, the direct assessment models may be forecasting actual proportional changes more closely than the comparisons indicate. A reasonable interpretation of the direct assessment predictions therefore is that they represent the expected average behavior of a transit system with given levels of the four attributes, holding natural disaster effects and seasonal effects constant. This supposition cannot be tested on the Xenia data and must await future work for validation. Nonetheless, because a considerable amount of the choice behavior in Xenia may be due to these exogenous influences, it deserves mention. Additionally, differences in monetary value of the costs of the various systems were not taken account of in forecasting back to each system. Thus, future work should adjust for inflation when calculating cost figures for retrospective prediction.

A final adjustment should be made for data which were omitted but which affect the final estimates of shares. A number of individuals

responded with category "1" or "2" on the response scale to all of the 18 alternatives. No equation could be estimated for these respondents because they have constant responses regardless of attribute levels; hence, they were removed from the forecasting system. Yet it is clear that these respondents are saying that they will probably <u>never</u> use transit. Their omission from the data set is tantamount to biasing the shares in favor of transit. Predicted transit shares should all be adjusted downward by the proportion of such responses observed in the survey. This result would imply a lower initial response to the free bus, which would have probably been true if so many autos had not been destroyed. Likewise, the lower predicted values for 1977 would be much more consistent with observation in Xenia.

It appears that this preliminary test of the direct value assessment method has yielded positive results, although many unresolved questions remain. Some of these questions and potential extensions are explored in Chapter 6.

be calculated by counting the number of responses to each cell that were greater than zero, and dividing by the total number of respondents.

The results of these manipulations are shown in Table 6.1. The data of Table 6.1 appear to agree: relatively speaking, walking distance and cost have the greatest impacts on patronage in the case of work trips and their effects are similar in magnitude. However, in the case of shopping trips, the impact of walking distance becomes predominant: worth twice that of travel time, almost four times that of headway, and one-third more influential than cost. This finding parallels the results of Morgan (1977), who reported similar effects in Tuscaloosa, Alabama, among college students. Table 6.1 is also interesting in that it demonstrates an interesting link to actual data: the elasticities of the "regular user" should be comparable to existing data (since it is based largely on the numbers of regular users before and after a change), and indeed, are of the same magnitude as values reported in the evaluation.

Caution must be exercised in the interpretation of these figures because they are indeed relative: that is, these comparative values pertain only to the given domains and ranges spanned by the attributes. Hence, any differences in domains and ranges yields potentially different values. One can say, however, that for those systems whose operating levels fall within these ranges, one would expect (if Table is representative) that these relative impacts would be retained. A positive feature of the methodology is that it readily permits derivation and calculation of these figures. Likewise, if one suspects that a particular

6. IMPLICATIONS FOR DEMONSTRATION EVALUATION

6.1 Relative Importance of Cost and Service Tradeoffs in Xenia

The results of the direct value assessment approach permit a number of conclusions about relative tradeoffs. In particular, one can examine two measures which reflect these relative effects:

1. The proportion of total explained variation accounted for by each of the attributes can be derived. These measures can be compared because of the controlled, balanced nature of the sampling plan and because all respondents completed the same survey. The logic behind the separability of these sources of variation is explained in Chapter 4 (see, e.g., Equations 4.6, 4.8, and 4.9).

2. The elasticities of the responses with respect to the attributes can also be estimated. Two measures are available for this comparison: (a) the arc elasticity of the marginal response means from the experimental data with respect to the corresponding attribute levels, and (b) the arc elasticity of the marginal proportion of respondents who self-estimated themselves to be regular users. A "regular user" is defined as an individual who judged that they would use any one of the 18 alternatives more than half the time. Thus, regular users can appear in several different cells--technically, any response number greater than seven (7) on the scale was used as an indication that the individual would be a regular user for that system. Because the total number of respondents is known, the expected proportion of regular users can

be calculated by counting the number of responses to each cell that were greater than seven and dividing by the total number of respondents.

The results of these manipulations are given in Table 6.1. The data of Table 6.1 appear to agree: relatively speaking, walking distance and cost have the greatest impacts on responses in the case of work trips and their effects are similar in magnitude. However, in the case of shopping trips, the impact of walking distance becomes preponderant, being twice that of travel time, almost four times that of headway, and one-third more influential than cost. This finding parallels the results of Norman (1977), who reported similar effects in Tuscaloosa, Alabama, among college students. Table 6.1 is also interesting in that it demonstrates an interesting link to actual data: the elasticities of the regular user should be comparable to existing data (since it is based largely on the numbers of regular users before and after a change), and indeed, are of the same magnitude as values reported in the evaluation.

Caution must be exercised in the interpretation of these figures because they are indeed relative: that is, these comparative values pertain only to the given domains and ranges spanned by the attributes: hence, any differences in domains and ranges yields potentially different values. One can say, however, that for those systems whose operational levels fall within these ranges, one would expect (if Xenia is representative) that these relative impacts could be expected. A positive feature of the methodology is that it readily permits derivation and calculation of these figures. Likewise, if one suspects that a particular

TABLE 6.1

Relative Importance Comparisons

Trip Purpose	Attribute (Factor)	Method of Computing Influence		
		Explained Variance	η^* of Response[a]	η of Reg. User
Work	Headway	.228	N/A**	N/A
	Cost	.310	-.25	-.41
	Walk	.312	-.28	-.49
	Time	.151	-.14	-.25
Shop	Headway	.106	N/A	N/A
	Cost	.294	-.22	-.44
	Walk	.408	-.34	-.66
	Time	.192	-.17	-.35

* η is the symbol for elasticity.

**N/A means "not applicable" because its calculation is arbitrary.

area is a unique case, or at least different from Xenia, it is possible to derive new estimates quickly and cheaply for the area in question. This is discussed later in this chapter.

Thus, a major conclusion is that walking distance to the transit stop plays a particularly important role in transit choice; this is especially true in the case of shopping trips. By implication, therefore, route structure and coverage emerge as critical attributes to be considered in the design and evaluation of demonstrations. This result parallels the observed transit choice behavior in Xenia. That is, as route coverage and fare were changed to less desirable levels for the second and third fixed-route bus systems, patronage steadily declined. The combined effect of both the fare and route structure change (as reflected in average walking distances--see Table 5.4) was to significantly reduce patronage from fixed-route one to two; similarly, the slight increase in average walking distance caused by the route structure change for fixed-route three resulted in further patronage reductions. These reductions parallel the results predicted by both of the direct response model systems (disaggregate and aggregate).

6.2 General Applicability of the Technique to Other Demonstration Projects

The technique of direct response assessment explored in this research project appears to have application to a variety of demonstration questions which follow:

1. It can be used to assess the likely consequences of the project prior to committing all project resources. Because one can use this approach to anticipate the likely outcomes of the proposed demonstration beforehand, an important application would be to conduct a "before" study to examine not only the consequences of a particular alternative under consideration, but to examine a range of alternatives. In this way one could spot potential disappointments prior to total commitment of resources, and likewise one could identify potentially positive alternatives, as well. Similarly, questions regarding optimization of resources could be addressed. It is recommended, however, that a series of "before/after" studies be conducted in which this technique is applied independently of the demonstration decision(s) to see if its accuracy of prediction is good and whether the results are consistent with system performance. In this way, confidence in the technique can be gradually achieved, although some applications and their benefits can be achieved now.

2. Following from 1, it is possible to consider optimizing the configurations of cost and service to maximize community participation, private operator profits, etc., for given levels of resource allocation. This is because one has the ability to simulate both costs of operating various alternatives and some response measure of interest -- patronage,

for example. Thus, it is possible to conduct controlled simulation experiments easily and cheaply which will permit one to model both the response and cost surfaces and begin to address optimization issues.

3. If policy sensitivity of various groups to proposed alternatives is an important issue, it is possible to isolate groups of interest directly and develop models for them easily and cheaply and assess the likely impacts of alternatives on these groups, as well as the general, randomly sampled public. Because the method should prove relatively inexpensive with some further refinements discussed later (Section 6.3), one could update forecasts on a regular, short-term basis, if necessary.

4. Because the data are obtained entirely at the individual respondent level from instruments whose measurements are not in question (all respondents judge fixed levels of the attributes), it is possible to begin making comparisons across demonstration projects. For example, are differences in responses due to differences <u>between</u> urban areas or transit systems?

5. Because it is possible to estimate "threshold" effects for individuals, it is possible to predict those levels above or below which patronage for that individual will be zero. Because these values represent constraints or boundary conditions, it should permit one to solve two important problems: (1) prediction of the feasible choice set--only those alternatives in which <u>all</u> levels of <u>all</u> influential attributes are within the interior of the feasible boundary; and (2)

determination of whether these boundary conditions should be the subject of policy manipulation because their impact is shown to be different for different groups such as the elderly, the wealthy, solo drivers, etc.

6. It should also be noted that very strict limits were placed on the technique in this application. In most cases, respondents can be asked to judge up to 32 combinations, which typically allow the analyst to incorporate seven or eight variables in the experiment. This is as large or a larger number of variables than is typically included in other models. Current research in Wisconsin is applying this technique to a joint-trip frequency and mode choice model, so this approach can handle multiple dimensions of travel behavior. The technique can handle new mode and new scenario (e.g., gas unavailability) issues better than many other approaches, as it is not dependent on an existing data set. Thus, the technique offers the promise of great flexibility in many applications.

6.3 Issues to be Addressed in Future Applications

Although the results of this application are encouraging, a number of issues which bear on interpretation of results and ease of use should be considered in future work. A number of these salient issues are considered below.

6.3.1 Alternative Survey Approaches

It has been frequently suggested informally that a direct value assessment study requires a carefully controlled home interview or laboratory format. This is not true and the misconception is probably the fault of the researchers who have advocated its use: zealousness to extoll the virtues of controlled experimentation has undoubtedly conveyed the impression that "controls" extend to all facets of the study. While this is certainly desirable, it is rarely, if ever, practical. The notion of "controls" as it is used in this report has to do mainly with the design of the experimental plan and how the response data can be interpreted rather than extending controls to interviewing, measurement and the like.

Hence, some practitioners have mistakenly fostered the impression that alternative survey formats were inappropriate. As mentioned in Section 6.2, however, the majority of applied work with the technique has been through the use of self-administered forms: drop-off or mail-out surveys. Sampling is based upon the requirements of particular studies, but will frequently require a random and/or choice-based procedure.

If the instructions are carefully prepared and pretested, there should be little problem with self-administration. As a matter of procedure, names and contact telephone numbers should be included so that anyone with problems can easily have questions answered. To date, however, there have been virtually no questions, and the follow-up sampling that has been done has consistently indicated that respondents have few difficulties. The singular exception is this Xenia study. The response scale probably was confusing to the respondents not only because of the placement of the verbal labels, but because it is difficult for respondents to self-estimate probabilities or likelihoods.

This is a minor technical problem that can be rectified in several ways: (a) change the response scale to one which is more easily understood, such as degree of preference, or to a discrete choice format where the respondent must select that mode that they would "most likely" use; (b) change the scale to reflect a comparison between one fixed mode such as auto alone and other choices; this could also be done in a discrete choice format.

In any case, in the future, a variety of cheaper ways of obtaining responses other than home-interview techniques should be explored, as should a variety of procedures to facilitate respondents' understanding of and responding to the alternatives. A moderate amount of preliminary or pilot work that was not possible in the Xenia project could be very valuable to future work and should be undertaken prior to any future applications so that potential problems can be assessed before actual data collection.

If one considers alternative means of obtaining response data, a variety of analytical devices are available in addition to multiple regression and analysis of variance that were employed in this study. These include conjoint analysis procedures developed for rank-order response data and the rank-order analogs to analysis of variance, and discrete multivariate analogs to regression and analysis of variance for multinomial response data. In all cases, these methods yield interpretations analogous to those discussed under factorial designs and the theory of functional measurement (see appendix). The difference is in the type of data obtained and its treatment. Nonetheless, the basic principle of estimating and testing effects is common among all these approaches to the problem.

A final and potentially interesting approach is to employ 5, 7, 9 or 11 category scales commonly used in so-called attitude studies and view their analysis from a different perspective. One can treat each category as an indifference value, or a group of indifference values, and ask whether a discriminant function can be derived that will maximize the differences between categories based on the set of predictor attributes. This would permit one to construct composite indifference surfaces over all respondents and treat the data from a new perspective. Obviously, if one has the indifference surface, one can reconstruct the response or value surface of interest.

A positive feature of these methods is that they are very complementary. If one is careful, one can obtain data that can be analyzed from a variety of perspectives and establish "convergent validity," the ability of all techniques to reach similar conclusions.

6.3.2 Interface and Comparison with Other Disaggregate Modelling Strategies

A major strength of the present approach is that it can interface well with existing methods. In particular, the approach can contribute significant new information regarding appropriate functional forms for the arguments of disaggregate models (Lerman and Louviere, 1978). Even in situations where less-than-complete information is available regarding all effects from a complete factorial, one can still make inferences about marginal functions and usually about one or more joint effects. Such information, while incomplete, is still better than the usual assumptions regarding linearity and additivity. Likewise, a number of alternative forms can be tested on the response data easily and cheaply to guide estimation of a revealed behavior-based disaggregate model.

Furthermore, because one has the ability to test for differences in coefficients as a function of differences among individuals on various market segmentation criteria, one can assist in the specification of expanded models for demand analysis by specifying *a priori* those terms which are likely to be significant in the revealed behavior-based model. Additional strength is contributed by the ability of the approach(es) to consider attributes whose range of variation is either limited or

non-existent in the real world and to introduce new alternatives, the response to which has not yet been assessed. These strengths complement the weaknesses of traditional travel demand modelling approaches.

The weaknesses of the approach are transparent. One must assume a rank-order correspondence between predicted values and real behavior. Although this is apparently not an unreasonable assumption, it warrants additional testing before being accepted. Thus, some consistent mapping of self-conceived measures or values into real choices or frequency of choices is needed. Also, appropriate transformations of physical or engineering measures are necessary to yield the appropriate estimates of cost, time, etc., in the models. The Xenia results suggest that this may not be as much of a problem as first imagined, but additional attention should be directed towards it. However, it is precisely in this area that traditional travel modelling procedures are strong and complementary.

Yet in Xenia, no disaggregate model could be successfully estimated. Thus, the potential significance of this new approach is great if the problems posed in the above paragraph can be solved. It represents a practical, straightforward way to obtain demand estimates even in situations where real-world variation is a problem.

6.3.3 Finding Appropriate Measures for Attributes

Although alternative measures of costs and times were employed in the choice simulations, it would be useful to know which of these measures or which other measures are most appropriate. This is an important question because one cannot tell whether the forecasting errors are

due to inadequacy of the models or the measurements or both. It would clearly be beneficial to separate these two error problems out in future work.

6.3.4 Expanding the Number of Alternatives Evaluated

The number of attribute combinations is an important issue for future work. Virtually all previous experiences with direct assessment procedures have used considerably more than 18 combinations (alternatives or scenarios). As discussed in Chapters 4 and 5, the small number of combinations, as well as some peculiarities of the Xenia transit environment, led to confounding or correlation of attributes which prevented the estimation of mode-specific effects for times, costs and walking distances. A slight modification in design strategy could overcome these limitations and vastly expand modelling capability.

In particular, several <u>different</u> sampling plans could be used, each assigned on an equal probability basis, to develop rather complete information about all (or most) marginal and joint effects of the attributes. For example, one survey form could capture as much bus information as possible, a second could capture paratransit and a third could capture both. By pre-specifying exactly what information is desired, it is almost always possible to develop alternative designs to obtain the information. It is encouraging that a single sampling plan obtained as much information as was reported in Chapter 5, but slight changes could yield considerably more information.

6.3.5 Expanding the Number of Attribute Dimensions

It is also possible to greatly expand the number of attributes or variables which are investigated. Research completed this past year indicates that at least 13 attributes can be examined and reliable data obtained from respondents without requiring a very large number of combinations.[1] In fact, the study at the University of Iowa is employing a 10-attribute sampling plan in which respondents will make 38 to 40 judgments. A preliminary version of this instrument is included in the appendix. There will be five different instruments, each randomly assigned to sample individuals; within each instrument, all marginal functions (main effects) and some joint functions (interactions) are estimable. Across all five instruments, <u>all</u> effects are estimable. Thus, it can be seen that increasing the number of attributes need not necessarily greatly increase the number of combinations. Moreover, previous experience with large multi-attribute designs has demonstrated that individuals readily reduce complexity by selecting only those attributes salient to them and ignoring the remainder. This has the side benefit of providing data regarding which attributes are considered in choice and by whom.

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[1] The study in question involved two residential preference assessment studies conducted in Laramie, Wyoming. Both involved random samples of individuals from Laramie; one used 11 attributes, the other used 13. Data are very reliable.

6.3.6 Alternatives to Home Interviews

Other types of survey or interview formats in addition to home or personal interviews should be examined. Most previous applications of the technique have employed a self-administration format rather than an interview. This can be accomplished in a number of ways:

1. Contact prospective respondents by telephone and explain the study to them and ask them to participate and to make a commitment to complete a survey which will be sent by mail. Immediately send the survey with detailed and easy-to-understand instructions regarding self-administration. Include phone numbers which respondents can call if they need something explained. Previous work with this procedure has usually resulted in response rates of 70 percent or higher with few refusals.

2. Contact individuals personally at home and elicit a commitment to participate if the survey is left with the respondent to be completed. As in procedure 1, response rates are usually high and refusals low. Response rates in excess of 85 percent have been achieved when the contact person makes an appointment to return and collect the completed survey rather than letting the respondent mail it back.

3. Mail-out and mail-back formats have also been used in the past, but the usual low response rate of 25-35 percent has served to discourage its use. When used, however, there has been little indication that respondents had any more or less difficulty than with the other procedures. However, no complex designs which have been used in recent

studies have been administered in this manner. Therefore, one can say that moderately complex designs yielded satisfactory results, but there is no available data on complex designs.

6.3.7 Problems of Missing Data

In the future it should be stressed to all respondents that all questions should be completed to the extent possible. Missing data in the Xenia survey increased the difficulty of analysis and interpretation and resulted in a loss of a considerable amount of data which was only partially complete. A few simple reminders in the survey or from the interviewers would largely obviate this problem.

6.4 Summary of Conclusions

The following conclusions may be reached regarding the results of this pilot research:

1. The results permit the conclusion that the direct response assessment approach can play a useful role in the design and evaluation of demonstration projects. Because surveys can be taken before as well as after a demonstration, and even during the demonstration, it is possible to guide design, monitor performance and evaluate results. A number of useful measures of likely system performance can be obtained, such as predictions of patronage, elasticities with respect to service, and cost tradeoffs and differences in response and impacts for different traveller groups. Although tentative, results are highly suggestive of this potential.

2. It is clear that one can directly estimate response functions for individuals and that these functions do bear some relationship to their real choice behavior. Indeed, previous research has already demonstrated that fact, and this study confirms it in a new context. Some mechanism needs to be found, however, for deciding how to eliminate some individuals from the forecasting system whose equations are clearly wrong, biased or error-laden. One suggestion is to eliminate all equations that do not have overall F values significant at least at the .1 or .2 level.

3. The research results demonstrate that utility coefficients vary systematically with various market segment measures, including a number of segmenting measures not previously considered. More importantly, the

results--at least tentatively--permit the conclusion that an a priori analysis of this type could suggest a variety of expanded demand models that might be examined within several different modelling approaches. If the direct response assessment survey approach can be accomplished cheaply, it might prove to be a valuable partner to more expensive travel modelling efforts that employ detailed home interview data on travel choices.

4. The research results suggest that the direct response assessment approach has the potential to be developed as a disaggregate forecasting system, different in some respects from current disaggregate modelling methods. It appears to have strengths where the other approach is weak, such as the ability to build variation into the alternatives which is not present in the real world and to include variables whose effects now can be only speculated upon either because there is currently only constant variation in attribute levels or the attributes are not yet influential in the choice process.

5. The research results also suggest that one of the strong advantages of the direct response assessment approach is its ability to uncover non-linear marginal and joint effects of choice variables. Thus, it offers the potential to generate a priori information regarding non-linearities to planners and choice modellers. The results also demonstrate that the method of orthogonal polynomials has great potential for detecting non-linearities which should be explored in current methods, as well as future applications, of this approach.

6. If future research confirms the validity of the approach, it should be possible to apply these methods very quickly and cheaply to selected "market panels" of individuals in local areas. These panels would be so chosen as to be representative of the population, and response equations could be updated as often as desired with this panel to permit one to continuously make short-range predictions, for two to five years ahead, for example. A side benefit of this type of approach would be the collection of a considerable amount of longitudinal data on travel choices, utility coefficients, and interpersonal measures which would permit one to begin to realistically assess dynamics.

U is the vector $(U_1, \ldots, U_I)$

B is an actual choice or behavior in a nonexperimental situation

I is the number of available alternatives

K is the number of variables

f_{ki}
g_i are all functions
h

In many cases, the X_{ki}'s may include factors for which the corresponding Y_{ki}'s are difficult to measure or not well understood. For example, automobile safety may affect a person's choice of auto type, but its [illegible] references are not well known. Such factors are treated in this theory below as distinct, qualitative variables and are part of the x_{ki}'s.

As developed above, this theory allows for responses, perceptions, and behavior over any set of discrete alternatives, indexed as $i = 1, \ldots, I$. For example, one might be interested in mode choice behavior, in which there are different factors influencing the desirability of driving alone, carpooling, taking transit, etc. In many situations, however, the behavior of interest is continuous and involves only one alternative. In these instances, the theory cited can be reduced to the case $I = 1$, and the i subscript can be deleted. However, because in this case study we are concerned with people's choices among discrete alternatives, we will retain the full notation except as noted.

Each of these assumptions is restated more formally below, and the case of additive and multiplicative utilities is explored in detail.

APPENDIX A

Algebraic Theory for Direct Value Assessment

Overview of Functional Measurement

As used in this context, the term functional measurement describes an approach to modelling individual behavior which is characterized by two aspects. First, functional measurement is based on an explicit theory of how people reach decisions. Second, it uses laboratory-like experimental measurement methods to estimate models rather than observations on people's revealed preferences.

Functional measurement is based on theoretical and empirical research in mathematical psychology and related fields, where there is extensive support for the following assumptions:

$$x_{ki} = f_{ki}\ (X_{ki}) \tag{1}$$

$$U_i = g_i(x_{1i}, x_{2i}, \ldots, x_{ki}) \tag{2}$$

$$B = h(U) \tag{3}$$

where:

- X_{ki} are physically measurable attributes of the alternative under study;
- x_{ki} are the values of X_{ki} as perceived by individuals;
- U_i is some level of response (such as numerical judgments, rankings, or choices) which are observed in an experimental context for alternative i. (For the purpose of this paper, we shall refer to this response as utility.)

U is the vector $(U_I, \ldots, U_I)$

B is an actual choice or behavior in a nonexperimental situation

i is the number of available alternatives

k is the number of variables

$\left.\begin{array}{l} f_{ki} \\ g_i \\ h \end{array}\right\}$ are all functions.

In many cases, the X_{ki}'s may include factors for which the corresponding x_{ki}'s are difficult to measure or not well understood. For example, automobile safety may affect a person's choice of auto type, but its physical referrents are not well known. Such factors are treated in this theory below as distinct, qualitative variables and are part of the x_{ki}'s.

As developed above, this theory allows for responses, perceptions, and behavior over any set of discrete alternatives, indexed as $i = 1, \ldots, I$. For example, one might be interested in mode choice behavior, in which there are different factors influencing the desirability of driving alone, carpooling, taking transit, etc. In many situations, however, the behavior of interest is continuous and involves only one alternative. In these instances, the theory often can be reduced to the case $I = 1$, and the i subscript can be deleted. However, because in this case study we are concerned with people's choices among discrete alternatives, we will retain the full notation except as noted.

Each of these assumptions is restated more formally below, and the case of additive and multiplicative utilities is explored in detail.

Assumption 1

For any observed travel behavior there exists a set of independent factors which are functionally connected to its occurrence or the magnitude of its occurrence. Each factor may be either quantitative or qualitative in nature. We shall denote the set of J quantitative factors by $S_i = (S_{1i}, S_{2i}, \ldots, S_{Ji})$ and the set of L qualitative factors by $Q_i = (Q_{1i}, Q_{2i}, \ldots, Q_{Li})$; $J + L = K$. The entire vector X_i is simply S_i and Q_i.

Assumption 2

Associated with each quantitative and qualitative factor is a corresponding value or quantity of its magnitude which may be obtained by one of several psychological measurement procedures. We shall let the utility of this quantity provided by one or a group of subjects by $(u_{1i}, u_{2i}, \ldots, u_{Ki})$. Because there may be K different values or corresponding utilities for each of the K factors, we may represent the utilities as u_{ki}. Formally, we postulate that

$$u_{ki} = f_{ki}(x_{ki}) \tag{4}$$

Assumption 3

In an experimental context we observe a response to a combination of $(S_{1i}, S_{2i}, \ldots, S_{Ji}, Q_{1i}, \ldots Q_{Li})$ on a psychological measurement scale. We assume that this response measure is connected to the utility of the experimental factors according to some algebraic combination rule. If we agree to let U_i represent the response to the i^{th} alternative,

$$U_i = g\ (x_{1i}, x_{2i}, \ldots, x_{Ki}) \tag{5}$$

The vector of responses (U) is connected to the observed travel behavior by means of some algebraic function. Hence, if we agree to call the observed behavior B, then we can write:

$$B = h(U) \tag{6}$$

Then by substitution,

$$\begin{aligned} B &= h(U) \\ &= h(g(x)) \\ &= h(g(f(S,Q))). \end{aligned} \tag{7}$$

This is too general a formulation for modelling purposes; in a practical application, it is necessary to make explicit assumptions about f, g, and h and deduce their consequences. The results lead to a general paradigm for the analysis of travel behavior which has growing empirical support. (See Levin, 1976 and 1977.)

The critical component of this theory for the purposes of developing appropriate functional forms for travel demand models is the specification of $U_i = g\ (x_{1i}, x_{2i}, \ldots, x_{ki})$. Analysis of variance provides a straightforward means of implementing the theory and diagnosing and/or testing alternative functional forms. In this study, we will consider both the linear and multiplicative cases. There are two key conditions involved in the application of analysis of variance that must be satisfied:

(1) The pattern of the statistical significance (or nonsignificance) of the utility responses to various combinations of the independent variables must be of a specific nature so as to permit inference (diagnosis) or testing of model form; and

(2) corresponding graphical evidence must support the inference or test.

Consider the hypothesis that individuals in the experiment outlined in the survey will trade off time and cost of travel independently of one another. That is, they combine the effects of these two variables linearly. This hypothesis may be tested directly by an analysis of variance. If for clarity we suppress the subscript "i" and write:

$$U_{mn} = U_m^1 + U_n^2 + \varepsilon_{mn} \tag{8}$$

where:

U_m^1 are the utility values assigned to the m^{th} level of the first factor (say, time) in a factorial experimental plan,

U_n^2 are the utility values assigned to the n^{th} level of the second factor (say, cost),

U_{mn} is the overall utility assigned by individuals to combinations of levels of factors 1 and 2, and

ε_{mn} is a random error term with zero mean.

The test for independence of the two effects (time and cost) corresponds to the test of the significance of the interaction "effect" of $U_m^1 \cdot U_n^2$. In an analysis of variance, this is a global test for any and all interaction effects between travel time and cost. If the interaction is not significant (i.e., the hypothesis that U_m^1 and U_n^2 combine linearly cannot be rejected), then the linear form may be accepted; if the interaction

is significant, it signals that some form other than a simple linear combination is appropriate. This test is accompanied by a graphical plot of the interaction. If the hypothesis of linearity is correct, the data should plot as a series of parallel lines when plotted against either U_m^1 or U_n^2 values on the abscissa. To see why, assume the linear form to be correct, and consider the effect of subtracting level 1 from level 2 of the first factor. This yields:

$$U_{2n} - U_{1n} = (U_2^1 + U_n^2) - (U_1^1 + U_n^2) + (\varepsilon_{2n} - \varepsilon_{1n}) \tag{9}$$

$$= U_2^1 - U_1^1 + (\varepsilon_{2n} - \varepsilon_{1n})$$

where U_1^1 and U_2^1 are the utility values assigned to levels 1 and 2 of factor one, respectively. Thus, the difference between the points when U_n^2 takes on any value is always a constant $U_2^1 - U_1^1$ (except for disturbances); hence, the graph should yield a series of parallel lines.

Note that this is true regardless of the forms we assume for the marginal relationships (i.e., $U_m^1 = f_1(X_m)$ and $U_n^2 = f_2(Z_n)$). It can be demonstrated that a measure of the average effect or utility (the so-called marginal utilities) of each of the two variables is given by their marginal means. We now demonstrate that this is true for <u>any</u> multi-linear utility model, confirming thereby that it holds for any more restricted form such as simple addition or multiplication.

If the data were obtained from a factorial design in which factor one is the row factor (subscripted m) and factor two is the column factor (subscripted n), we may write the most general multi-linear form as follows:

$$U_{mn} = k_0 + k_1 U^1_m + k_2 U^2_n + k_3 U^1_m \cdot U^2_n + \varepsilon_{mn} \qquad (10)$$

where all terms are as defined previously and the k's are scaling constants. Additional factors simply add additional one-, two-, three-, and higher-way terms. Now, if we average the factorial data over the second subscript n (i.e., the column factor), we would have:

$$U_{m.} = k_0 + k_1 U^1_m + k_2 \overline{U}^2_n + k_3 U^1_m \cdot \overline{U}^2_n + \varepsilon_{m.} \qquad (11)$$

where $\overline{U}^2_n$ is the average over the column factor. Thus, Equation 11 reduces to:

$$U_{m.} = K_0 + K_1 U^1_m + \varepsilon_{m.} \qquad (12)$$

where the K's are collected terms. Equation 12 demonstrates that the marginal row means (in general, the marginal means for any subscript), are equal to the marginal utilities up to a linear transformation. Hence, they are as "good" as any other estimate measured on an interval scale. Equation 12 is important because it demonstrates that an estimate of the marginal utility for any factor may be obtained by manipulating that factor as part of a factorial or fractional factorial design so long as <u>any</u> multi-linear utility function can be assumed to have generated the data.

Returning to the reduced strictly additive form, it may also be demonstrated that these marginal means relate to the overall utility value of cell m,n as follows:

$$U_{mn} = U_{m.} + U_{.n} - U_{..} + \varepsilon_{mn} \tag{13}$$

where $U_{..}$ is the grand average utility (mean). Similarly, for a strictly multiplicative form, it may be demonstrated that the following is true:

$$U_{mn} = k + [(U_{m.} - k)(U_{.m} - k)/(U_{..} - k)] + \varepsilon_{mn} \tag{14}$$

where all terms are as defined in Equation 13, except for k which is a scaling constant which represents the arbitrary zero point on the utility scale.

Now, in the assumption that Equation 12 is true, we may write the following expressions by assigning levels of cost to the rows and levels of travel time to the columns:

$$U_{m.} = f_1(\text{cost}_m) \text{ and} \tag{15}$$

$$U_{.n} = f_2(\text{time}_n), \tag{16}$$

because the only source of variation in $U_{m.}$ and $U_{.n}$ is that due to the levels of cost and travel time and error. Thus,

$$U_{mn} = f_1(\text{cost}_m) + f_2(\text{time}_n) - U_{..} + \varepsilon_{mn} \tag{17}$$

if the two factors combine additively, or

$$U_{mn} = \{[f_1(\text{cost}_m) \cdot f_2(\text{time}_n)]/U_{..}\} + \varepsilon_{mn} \qquad (18)$$

if the factors combine multiplicatively and we assume that k in Equation 14 equals zero as a first hypothesis.

Following our previous logic, Equation 18 is testable statistically and graphically. In particular, Equation 18 requires that all interaction effects be statistically significantly different from zero and that the graph of the interaction must consist of a series of diverging curves. An exact statistical test may be obtained by using the marginal means as the independent values, estimating k (usually done by iterative methods) and performing the following linear regression:

$$\ln(U_{mn} - k) = \ln(U_{m.} - k) + \ln(U_{.n} - k) - \ln(U_{..} - k) \qquad (19)$$

If Equation 18 is true, the coefficients of the cost and travel time terms should not be significantly different from 1.0.

Thus, we have demonstrated than an algebraic and statistical theory to diagnose and test <u>any</u> multi-linear utility form exists. In order to derive a model in the units of the original variables (e.g., miles, minutes, dollars), it is necessary to first diagnose the overall form of Equation 10, and then make assumptions about the functions in Equations 17 and 18 (or a more general form given by Equation 10, if appropriate).

to one another and therefore [illegible] and testable. The problem arises, in [illegible], [illegible] non-balanced data collection schemes such as the design in the [illegible] survey (which is nearly orthogonal) and the usual "revealed behavior" data such as that obtained in the detail travel or trip data in the survey. That is, it is usually the case that travel times and costs are correlated in real data and there is not a balanced sampling of high costs and high times, high costs and low times, low costs and high times, and low costs and low times, with equal numbers of observations in each of these conditions. It would be desirable to be able to estimate a non-linear marginal effect for both time and cost, independently of the linear effect of time and cost, as well as any interactions between the two factors, as they may affect the dependent variable. While it cannot remove the collinearity between the linear components of time and cost, the method of orthogonal polynomials can remove <u>all</u> correlation between time and time squared and between cost and cost squared and reduce the correlations between the various cross-products and these other effects, as well. In particular, the method of orthogonal polynomials has the property that it provides an exact test for the <u>highest-order effect</u>. Thus, if a squared term is appropriate in the model, this method will find it with a high degree of confidence. Lower terms--for example, linear terms--are estimated with less precision, because, as we shall demonstrate, the higher terms are really composites of the lower terms. Hence, the presence of a significant squared term implies that there is a real quadratic effect, but if the linear term

APPENDIX B

Purpose and Method of Construction of Orthogonal Polynomial Contrasts

The purpose of orthogonal polynomial contrasts is to permit one to make inferences regarding polynomial terms in an expanded linear equation, as well as to make inferences regarding the significance of cross-product (interactions) terms. That is, it is not generally possible to test x_1, x_2, x_1^2, x_2^2, $x_1.x_2$, $x_1^2.x_2$, $x_1.x_2^2$, $x_1^2.x_2^2$, each as separate terms in a model which includes all of these effects because of the collinearity problems which result. Although it is frequently alledged that collinearity is a "sample size" problem, this is at best misleading. Rather, collinearity should properly be viewed as a problem of confounding of effects, such that one cannot really say whether one is estimating x_1 or some other term that might be highly correlated with x_1. Hence, for various reasons, not the least of which is interpretability, collinearity should be reduced to as minimal a level as possible. The method of orthogonal polynomials accomplishes this in a straightforward manner, but at the sacrifice of "direct" interpretation in the original units of measurement. However, as we shall note, it is always possible to return to the original units in a straightforward manner and to interpret some of the effects directly, as well.

In the situation in which one were to have a balanced factorial sampling plan for obtaining observations, the method of orthogonal polynomials guarantees that <u>all</u> possible testable effects will be orthogonal

to one another and therefore linearizable and testable. The problem arises, therefore, in non-balanced data collection schemes such as the design in the Xenia survey (which is nearly orthogonal) and the usual "revealed behavior" data such as that obtained in the detail travel or trip data in the survey. That is, it is usually the case that travel times and costs are correlated in real data and there is not a balanced sampling of high costs and high times, high costs and low times, low costs and high times, and low costs and low times, with equal numbers of observations in each of these conditions. It would be desirable to be able to estimate a non-linear marginal effect for both time and cost, independently of the linear effect of time and cost, as well as any interactions between the two factors, as they may affect the dependent variable. While it cannot remove the collinearity between the linear components of time and cost, the method of orthogonal polynomials can remove all correlation between time and time squared and between cost and cost squared and reduce the correlations between the various cross-products and those other effects, as well. In particular, the method of orthogonal polynomials has the property that it provides an exact test for the highest-order effect. Thus, if a squared term is appropriate in the model, this method will find it with a high degree of confidence. Lower terms--for example, linear terms--are estimated with less precision, because, as we shall demonstrate, the higher terms are really composites of the lower terms; hence, the presence of a significant squared term implies that there is a real quadratic effect, yet if the linear term

is not significant in this case it does not mean that it is not significant. This is because the quadratic effect contains linear terms which would appear in the expanded equation. On the other hand, if both linear and quadratic terms were non-significant, this would imply non-significance for the entire effect. Thus, interpretation is somewhat cumbersome in that the entire term must be expanded to know its form, but this seems like little sacrifice in order to be able to estimate these higher order effects.

The particular approach that we adopted in this research project was patterned after an article by D.S. Robson (Biometrics, June, 1959, 187-191: "A Simple Method for Constructing Orthogonal Polynomials When the Independent Variable is Unequally Spaced"). As Robson demonstrates, a least-squares regression equation of the form:

$$Y_i = b_0^* + b_1^* x_j + b_2^* x_j^2 + \ldots + b_r^* x_j^r, \quad j = 1,\ldots,n > r$$

may be expressed in the following form:

$$Y_i = b_0 f_0(x_j) + b_1 f_1(x_j) + \ldots + b_r f_r(x_j), \; j = 1,\ldots,n > r$$

where $f_i(x_j)$ is a polynomial of degree i in x_j and where f_0, $f_1 \ldots f_r$ are normal orthogonal functions; i.e., where

$$\sum_{j=1}^{n} f_i(x_j) f_{i'}(x_j) = \begin{cases} 0 \text{ if } i \neq i' \\ 1 \text{ if } i = i' \end{cases}$$

The construction of the functions $f_r(x_i)$ is accomplished by application of the following formulae (for the linear and quadratic terms):

<u>Linear Term</u> $$f_L(x_j) = (x_j - \bar{x})$$

<u>Quadratic Term</u> $$f_Q(x_j) = x_j^2 - 1/n(\Sigma C) - (x_j - \bar{x})(\Sigma A/\Sigma B)$$

where:

$$\Sigma A = \sum_i x_i^2 (x_i - \bar{x})$$

$$\Sigma B = \sum_i (x_i - \bar{x})^2$$

$$\Sigma C = \sum_i x_i^2$$

Note that these formulae may also be applied to dummy variates, yielding a transformed dummy variate that has the values of $\pm$ the mean. When <u>all</u> variates are transformed to orthogonal form in this manner by centering about their means, the intercept estimates the zero order effect or the mean of Y. Higher polynomials may be derived by simply multiplying the linear term times the term in question, forming the mean of that term and subtracting it from each observation. Thus, the cubic is formed by multiplication of the linear and quadratic terms or by cubing the linear term and subtracting its mean from every observation.

This procedure may be readily applied to travel data used to estimate disaggregate choice models by transforming all variates to these forms and expanding the model as appropriate. To demonstrate the ease of returning

to the original units, we show the two forms of the work purpose model estimated on the cell averages from the survey. Recall the original orthogonal form of the model is:

$$U_i^W = 3.5089 + 0.3(TS_i) + 0.2(BH_i) - 0.65(TH_i) - 1.33(F_i)$$
$$- 1.22(F_i^2) - 0.32(W_i) - 0.01(W_i^2) - 0.05(T_i) - 0.0013(T_i^2)$$

By expanding the model form with the appropriate means, we derive the following expression:

$$U_i^W = 5.459 + 0.3(TS_i) + 0.2(BH_i) - 0.65(TH_i) - 0.111(F_i)$$
$$-1.22(F_i^2) - 0.253(W_i) - 0.01(W_i^2) - 0.047(T_i) - 0.0013(T_i^2)$$

Note that the dummy variates TS, BH, and TH are unaffected because they may be coded as convenient, and the quadratic terms have the same coefficients as above. As mentioned earlier, the quadratic terms are exact, but the linear terms must be adjusted to take account of the formulae at the top of the immediately preceeding page. The dependence of the linear term is essentially the square of the linear term, subtracting the mean of the quadratically transformed observation from each observation. Hence, we have:

$$(x_i - \bar{x})^2 - ([x_i - \bar{x}]/n),$$

and there is clearly an unbiased x_i^2 term, but x_i also contains $-2\bar{x}(x_i)$ which is involved in this quadratic term. This algebra clearly shows that

one gets a "real" test on the highest order terms, but the lower order terms must be reconstructed.

The orthogonal codes and the cell means for the design in the Xenia Home Interview Survey are given in Table 4.3.

APPENDIX C

Xenia Home Interview Survey

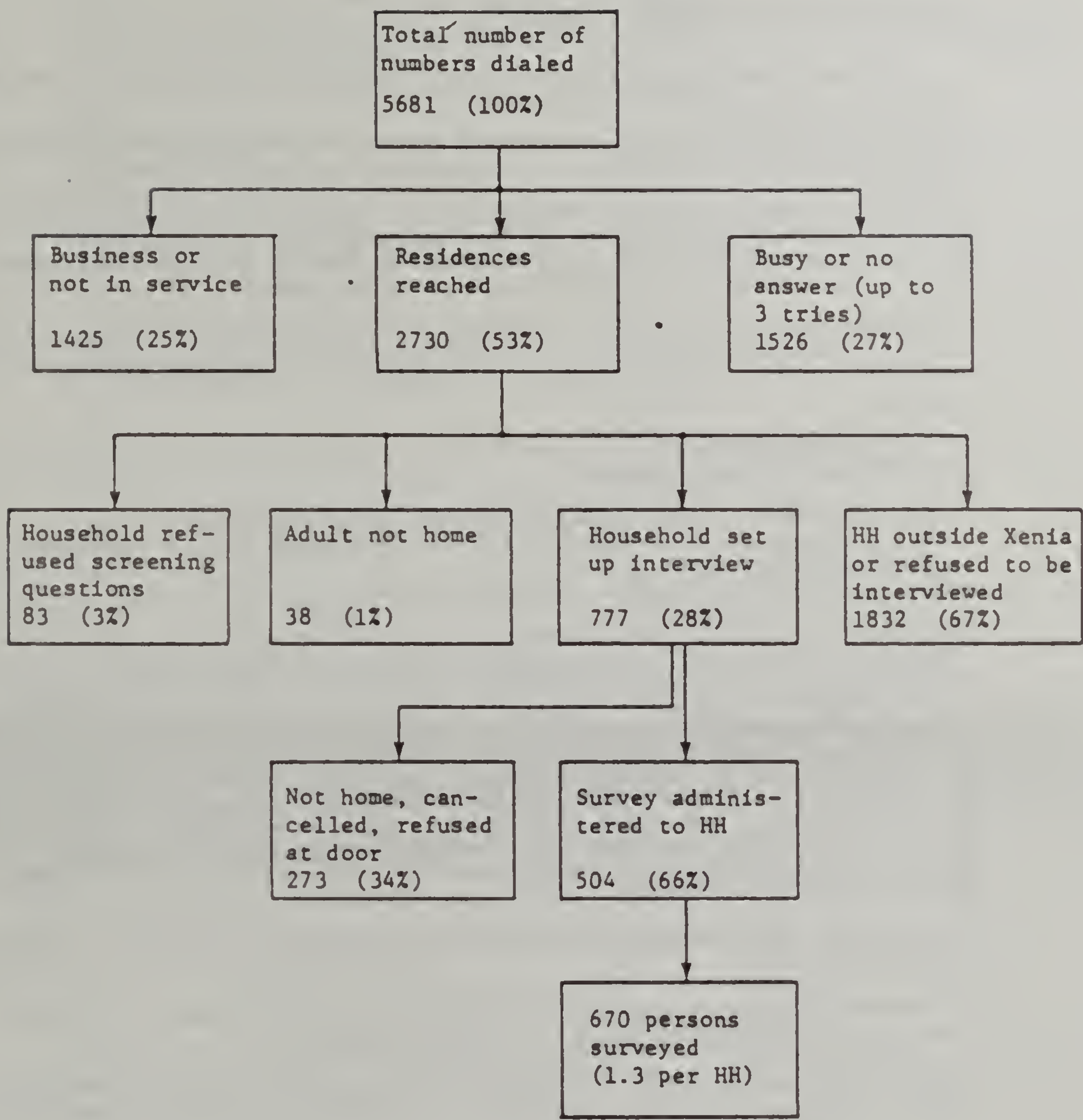

FIGURE 3.1: Results of Phone Screening and Interviewing, 1977

XENIA HOME INTERVIEW SURVEY
SCREENING INSTRUCTIONS

There will be two phases to the survey:

I - Telephone Screening
II - Home Interview

I. General Instructions - Telephone Screening

1. The telephone screening will be conducted between 5:30 p.m. and 9:30 p.m. on weeknights only, before the home interviews begin.

2. Each interviewer will have a list of numbers to call, this list should be transcribed onto the Telephone Screening Form. If the number reached cannot be asked the screening question, the interviewer should record the reason by marking the spaces provided; for example, if the number reached is a business phone, or the line is busy, the interviewer should place an "X" or checkmark under the column headed "business phone" or "busy." If the line is busy or there is no answer, this number should be placed on a "call back" list and called again later.

3. The interviewer should speak to an adult, and ask if the household's residence is within the Xenia city limits. If the household does not reside within the city limits, the interviewer should indicate this in the appropriate space and terminate the interview.

4. If the household does reside within the Xenia city limits, the interviewer should ask the following three key questions.

   - Were you a resident of Xenia when the tornado struck in April, 1974?
   - Has a member of your household used the X-Line or Flexicab public transportation system in the past year?
   - How many automobiles does your household own or operate?

   The interviewer should record the answers to the three key questions on the Telephone Screening Form by marking the appropriate box for each of the three questions asked. After the answers to the three questions have been recorded, the interviewer should refer to the "Category" matrix at the bottom of the form, which indicates the appropriate categorization of selected combinations of answers to the three questions. Each set of three answers will fit into one of the six categories indicated in the right hand column of this matrix. If the respondent's answers place him or her in a category that has not reached its target sample size, attempt to arrange an appointment, preferably during the evening. About one-half hour will be required, and whenever possible, there should be at least two respondents per household. The Flexicab user, if any, in the household, must be present. Strongly request the presence of the head of household, although it is not mandatory.

   If respondent, after being asked, refuses to be interviewed at home, mark "refused" in space for address.

   If respondent falls into category which already has a sufficient number of interviews scheduled, ask questions on Form X and terminate interview.

5. Quotas for categories IV, V, VI listed below do not need to be met; any shortfall in categories IV, V, or VI must be compensated for by additional scheduled interviews in I, II, or III, as indicated below.

Quotas for Scheduled Interviews in Each Category Shown on Form Tare:

I. 94 (or more)	IV. 24 (or less): Categories I and IV must together total 118.
II. 141 (or more	V. 35 (or less): Categories II and V must together total 176.
III. 188 (or more	VI. 47 (or less): Categories III and VI must together total 235.

6. Phone numbers will be selected by random digit dialing using a standard random number table, except that users of the Flexicab service will be found from a phone list drawn from system records to the extent possible.

7. All screening is to be carried out from a phone bank at ______________________________

8. All information from this survey is to be held in the strictest confidence.

TELEPHONE SCREENING FORM

Initials of Screener: ________

Phone number	Business Phone	Not in Service	Busy	No Answer - Call Back	Refused to Answer Question	Call Back when Adult is Home	Do you live within the Xenia city limits?		Quest. 1 Was your household in Xenia during 1974 tornado?		Quest. 2 Has any member used the Flexicar service in the last year?		Quest. 3 How many autos in household now?		Category	INTERVIEW INFORMATION Address	DATE	TIME
							yes	no	yes	no	yes	no	0,1	2+				

CATEGORY

CATEGORY	I	II	III	IV	V	VI
RUNNING TOTAL						
PAGE TOTAL						

Note: FORM X is not needed for Category IV.

Form X

Termination Questions for Telephone Screening

(To be used when a respondent's category quota has been filled.)

SKIP X1 IF RESPONDENT IS IN EITHER CATEGORY I OR IV.

X1. Are you aware of the Flexicab/X-Line service currently being operated by the Xenia Cab Company?

☐ YES ☐ NO

TERMINATE CALL IF RESPONDENT IS IN CATEGORIES V, OR VI.

X2. Were you aware of the Free Bus service after the tornado?

☐ YES ☐ NO IF NO, TERMINATE CALL.

X3. IF YES: Did you ever use it?

☐ YES ☐ NO IF NO, TERMINATE CALL.

X4. IF YES: If you are not presently using it, can you tell me why you stopped?

☐ "I heard it might stop."
☐ "It stopped being free."
☐ "A car became available."
☐ "No further need."
☐ "It was unreliable."
☐ "It was too slow."
☐ "It was inconvenient."
☐ Other ______________________

"Thank you very much for your cooperation."

XENIA HOME INTERVIEW SURVEY
INTERVIEWING INSTRUCTIONS

There will be two phases to the survey:
I. - Telephone Screening
II. - Home Interviewing

I. General Instructions - Home Interview

1. Interviewers should allow a half hour between interviews for travel time, delays, etc. Thus, interviews should be scheduled at one hour intervals for any single interview.

   Clock time (to nearest minute) should be filled in at points specified on the survey forms during pretest, first day of interviewing, and on a spot basis afterwards.

2. The interviewer is to obtain trip information on the trips made the day of the interview (i.e., if the interview takes place on Wednesday, obtain Wednesday only trips). If the respondents are aware of trips that will be made during the evening, they should also be included.

3. Form A should be administered to the more senior of the two household members; then continue with forms B, C and D for that person. After starting them on form D, leave them to complete it on their own, and begin with form B with the second person, continuing through forms C and D to complete the interview.

II. Specific Questions - Home Interview

Clarification is provided for some questions that may require interpretation:

(General) If respondent cannot answer a certain question, write "DK" (don't know) as response in the first blank provided for a response.

A3, A5 Number of Vehicles Owned or Operated by Family

Ask for the total number of vehicles that are available to the household. This can include all types of vehicles that are owned by the people including cars, trucks, vans, etc., but not motorcycles. Also included in this category would be company vehicles that are driven home. Inoperable, antique, or junk cars should not be counted.

A6. We are interested in knowing how many cars were destroyed or severely damaged to the extent that they could no longer be driven. Minor damages should not be counted.

A10. Although a selection of responses are listed for question A10, the interviewer should not read these answers aloud; the respondent should answer in his/her own words, and the interviewer must determine if the respondent's answer fits any of the listed alternative responses. If the respondent's answer does not correspond to one of the alternative responses listed, or if the interviewer is unsure how to categorize the response, the interviewer should record the respondent's answer in the "other" category, just as the respondent says it, to the extent possible.

B2. It is permissible on this question for the interviewer to prompt respondent by asking how many trips were taken for a specific purpose, e.g. "how many trips were for going to or from work?" as written on questionnaire. Both respondent and interviewer may be unsure how to categorize a particular type of trip. In this case, the interviewer should write the number of trips taken of this type and a short description of the trips in the blank space alongside the categorized responses, e.g. $\boxed{3}$ - "pick up groceries."

B4. In asking if the respondent has ever used the "Flexicab/X - line or Free bus", we really want to know if the person has used any of the City of Xenia public transit services since the tornado.

B10. Once again the interviewer is called upon to categorize an "open-ended" response. The respondent should describe his/her "major activity" in his/her own words, and the interviewer must determine if the response fits any of the listed response categories. The interviewer may prompt the respondent if necessary. For example, if the respondent says "work" is his/her major activity, the interviewer may ask "How many hours per week do you work" to determine if employment is full- or part-time.

B11. The interviewer should read through the question and the alternative responses aloud completely at least once, to familiarize the respondent with the choice of answers. Then the interviewer should re-read the question and each response aloud slowly, giving the respondent a chance to designate his/her choice when he/she feels ready to do so.

B12 - B15. The interviewer should read the question and response alternatives aloud at least once.

B17. If two or more persons in the household are taking the survey, the income question should be asked of only one; this person should be the head of household, if possible, or a responsible adult, i. e. the more ~~"senior"~~ person.

C. Trip Sheet

The Trip Sheet is to be used to obtain all the required information on the daily trips of the two members of the household interviewed. A separate form should be used for each household member interviewed and the interview number inserted. Each sheet should also be numbered consecutively if more than one sheet is required.

After completing preliminary information about an individual respondent (form B), the following information should be asked about each trip made by that person today. But first, what is a trip?

The most important element of the survey is the trip. Therefore, it is vital that each interviewer have a clear understanding of the exact definition of a trip.

A trip is defined as the one-way movement of a person by automobile or transit from one primary activity to another that is more than three (3) blocks away.

(EXAMPLES:
- A person driving from home to work directly is considered to be one trip.
- A person who drives to pickup 2 other people before travelling to work is considered to have made only one trip. In other words, his primary activities were home and work; we are not interested in his intermediate stops.
- A person driving from work to home but stops to buy some groceries is considered to have made two trips: work to shop and shop to home.
- Trips made as part of a person's employment (i.e., real estate brokers, delivery men, etc.) are not to be considered by the interviewer, and therefore not marked on the trip sheet.
- A person may go to a neighbor's for coffee and then go shopping. This would represent two trips, one to coffee and the other to shop. This would be a result of the time lag between the movements.
- Trips made on a school bus, bicycle, motorcycle or by walking (not a regular transit bus), are not included.

a) Trip Number

This is simply to be used to identify each individual trip. The first trip will be numbered 1 and so on. It is not important to maintain any particular sequence as to which trip should come first.

b) Time of Day

Ask the respondent the time the trip started. (AM or PM)

c) Trip Origin

The interviewer is to ask for the origin of the trip (that is, where did the trip start out from?). The location should be identified by specifying the nearest intersecting streets, e.g. Main and 2nd, except if home is the point of origin, in which case the interviewer can simply write the word "home", since we already have the respondent's address recorded.

d) Trip Destination

The same comments that have been made for the trip origins apply for the trip destination (where the trip ended). Remember that the more specific the address, the easier it will be to code the information later.

e) Trip Purpose

For all trips, the respondent should be asked the activity at the origin and destination. There are seven purpose codes used in this survey. The interviewer has the option of designating each of these seven trip purposes by the letter codes indicated or in words, but if the interviewer chooses to write out the response in words, he/she should use the exact code words indicated whenever possible. If the interviewer has difficulty classifying the response as one of the listed codes, he/she should record whatever the respondent says.

Note on trip purpose D, Chauffeuring : A trip activity should be recorded as "chauffeuring" only when the driver is the respondent, and transporting a passenger was the driver's only reason for making the trip. In this case, the interviewer should record code "D" or the word "chauffeuring" and the passenger's purpose, in the column headed, "What was the activity at your destination"; hence, there will be two trip activities appearing in the "activity at destination" column for this trip. The "activity at origin"for this trip would be the driver's activity at origin. If the driver starts a second trip from the place where he has chauffeured his passenger, the "activity at origin" of this second trip would be code D, chauffeuring.

f) Mode of Travel

There are six numerically coded modes of travel that are acceptable for the survey. (Remember, walking, bicycling, motorcycling and travelling by school bus are not included). The interviewer should use the identifying code number to record the mode for each trip.

Mode Definitions:

1. Auto - You drove alone: You drive a car in which there are no other passengers.
2. Auto - You drove with passenger: You drive a car in which there is at least one additional passenger.
3. Auto - You rode as a passenger: You ride in a car which is driven by another person.
4. Taxi - Ride alone: "Ride Alone" taxi service.
5. Taxi - Advanced, shared ride: Rider calls two hours in advance; rider may share the cab with another person.
6. Taxi - Immediate, shared ride: Taxi will pick up rider a few minutes after rider telephones; rider may share the cab with another person.

Sample responses on trip sheet:

a. A person uses the Flexicab immediate request, shared-ride service to travel from home to a store, at approximately 2:00 pm.

Trip would be recorded in the appropriate columns on Form C as follows. (Responses are underscored).

At what time did trip begin? 2:00 pm.
What are the nearest intersecting streets to your origin? home(home address recorded elsewhere)
What was the activity at origin? A
What are the nearest intersecting streets to your destination? Main and 8th
What was the activity at destination? C
What mode of travel did you use? 6

b. After completing his shopping, this same person walks one block to pick up his car at the garage, and at approximately 3:30 pm drives to pick up a friend and proceeds to an athletic field, where he and his friend are meeting others to play touch foot -ball.

Trip would be recorded as follows.

At what time did trip begin? 3:30 pm
. . . nearest intersecting streets to origin? Main and 9th
. . . activity at origin? C
. . . nearest intersecting streets to destination? Route 10 and Maple
. . . activity at destination? E
What mode of travel did you use? 2

c. After the game, at approximately 5:30 pm, the same person to the friend's music lesson, where the driver waits for his friend.

Trip recorded as follows.

At what time did trip begin? 5:30 pm
. . . nearest intersecting streets to origin? Route 10 and Maple
. . . activity at origin? E
. . . nearest intersecting streets to destination? Water and 7th
. . . activity at destination? D,G
What mode of travel did you use? 2

These data are CONFIDENTIAL and will be used for travel studies only.

CITY OF XENIA HOME INTERVIEW SURVEY - 1977

Form A

Household Data
(One for each household surveyed)

Date ______/______ Time ____________ ☐☐☐☐ Household I.D.

____
Address

ADMINISTER THIS FORM TO AN ADULT

A1. How many persons are living here in this household? ☐

A2. How many of them are over 12 years old? ☐

A3. How many automobiles does your household own or operate presently? ☐

A4. Did you live in Xenia when the tornado struck in April 1974?

☐ YES ☐ NO IF NO, GO TO FORM B

A5. How many automobiles did your household own or operate at the time of the tornado? ☐

A6. Were any automobiles destroyed or made inoperable by the tornado?

☐ YES ☐ NO IF NO, GO TO FORM B

A7. Did you replace or repair any of them?

☐ YES ☐ NO IF NO, SKIP TO A10

A8. How many automobiles did you replace or repair? ☐

A9. When did you replace or repair the damaged auto(s)?

auto #1 ________ Month ______ Year

auto #2 ________ Month ______ Year

GO TO FORM B

A10. Why didn't you replace or repair your destroyed or damaged autos?

☐ Transit available

☐ Needed to rebuild home

☐ Decreased income

☐ Other ______________________________

These data are CONFIDENTIAL and will be used for travel studies only.

Form B

Person Data
(One form for each person)

__________ Time   ______Person No. ☐☐☐☐ Household I.D.

B1. ASK QUESTION ONLY IF PERSON WAS A RESIDENT OF XENIA DURING TORNADO

Were you aware of the free bus service after the tornado of 1974?

☐ YES ☐ NO

Office Use

IF YES: Did you use it?

☐ YES ☐ NO

B2. Have you used the Flexicab/X-Line service in the last month?

☐ YES ☐ NO

IF YES: How many times? ☐

☐ Of those, how many trips were for going to or from work?

☐ for going shopping?

☐ for going to or from school?

☐ for any other reason?

IF YES, SKIP TO B6 ON NEXT PAGE

B3. Are you aware of the Flexicab/X-Line service currently being operated by the Xenia Cab Company?

☐ YES ☐ NO

B4. Have you ever ridden Flexicab/X-Line Bus or the Free Bus?

☐ YES ☐ NO IF NO, SKIP TO B6 ON NEXT PAGE

These data are CONFIDENTIAL and will be used for travel studies only.

B5. Why did you stop using the Xenia public transit service?

Office Use

- [ ] Inconvenient
- [ ] Heard that it might stop
- [ ] Unreliable
- [ ] Too Slow
- [ ] Stopped being free
- [ ] Other ______________________________

B6. What is your relationship to the household?

- [ ] Head
- [ ] Spouse
- [ ] Child over 12 years old
- [ ] Adult in shared household
- [ ] Other ______________________________

B7. OBSERVE, DO NOT ASK   Sex of respondent

- [ ] MALE   [ ] FEMALE

B8. How old are you, approximately?

IF UNDER 16, GO TO B16

B9. Do you have a valid driver's license?

- [ ] YES   [ ] NO

These data are CONFIDENTIAL and will be used in travel studies only.

Office Use

B10. What is your major activity?

- [ ] Work full-time (30 or more hours per week)
- [ ] Work part-time (8 to 29 hours per week)
- [ ] Student (grade or high school)
- [ ] Student (College)
- [ ] Home Duties
- [ ] Retired
- [ ] Unemployed
- [ ] Other ____________________

IF NOT A LICENSED DRIVER, SKIP TO B16.
IF UNEMPLOYED, SKIP TO B13.

B11. Let's talk about your trip to work. Do you generally have an automobile available to drive to work?

[ ] YES [ ] NO IF NO SKIP TO B13

Now, I'm going to ask you to compare driving your car to riding the Flexicab/X-Line service. For your information, the average Flexicab fare is 75 cents. For your trip to work, is driving your car

(check one)

- [ ] much more expensive,
- [ ] slightly more expensive,
- [ ] about the same cost,
- [ ] slightly cheaper,
- [ ] much cheaper

than taking Flexicab?

B12. For the same work trip, is driving your car

(Check one)

- [ ] much faster
- [ ] slightly faster
- [ ] about the same
- [ ] slightly slower
- [ ] much slower

than taking Flexicab?

These data are CONFIDENTIAL and will be used in travel studies only.

Office Use

B13. Now, let's talk about shopping trips. Do you generally have an automobile available to drive for shopping trips?

☐ YES ☐ NO IF NO SKIP TO B16

B14. For your average shopping trip, is your car

☐ much more expensive
☐ slightly more expensive
☐ about the same cost
☐ slightly cheaper
☐ much cheaper

than riding Flexicab? (Average fare 75 cents)

B15. Once again, for your average shopping trip, is your car

☐ much faster
☐ slightly faster
☐ about the same time
☐ slightly slower
☐ much slower

than riding Flexicab?

B16. In your own words, what are the major reasons you do or do not use public transportation.

____

____

____

B17. ASK THIS QUESTION ONLY TO MOST SENIOR RESPONDENT.

HAND RESPONDENT THE INCOME CARD.

Please tell me the letter corresponding to the total income of your household. ☐

GO TO FORM C

INCOME

A. Under $5,000

B. $5,000 - $9,999

C. $10,000 - $14,999

D. $15,000 - $19,999

E. $20,000 or over

TIME_______________

Form C

Travel Diary
(One for each person)

READ TO THE RESPONDENT:

Now, I'm going to ask you about all the trips you've made today and any others you are planning to make later. Please include all trips, even ones that may seem unusual for you to make. For each one of your trips, I'll ask you what time you started, the place you started, the place you went, the activities at both locations, and the means of transportation you used. Please describe your trip origins and destinations by indicating the nearest two intersecting streets in each case.

HAND RESPONDENT THE ACTIVITY AND MODE OF TRAVEL CARD.

CONTINUE READING:

Now, when did you begin your first trip today?

CONTINUE QUESTIONING ON THE NEXT PAGE.

Form C

Trip Diary

(One for each person)

Household I.D. ☐☐☐☐

Person Number ________

Trip No.	At What time did the trip begin?	What are the nearest intersecting streets to your origin?	What was the activity at the origin?	What are the nearest intersecting streets to your destination?	What was the activity at the destination?	What mode of travel did you use?
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						

CODES

ACTIVITY
A. Home
B. Work
C. Shopping
D. Chauffeuring
E. Recreation
F. Personal Business
G. Other

MODE OF TRAVEL
1. Auto - You drove alone
2. Auto - You drove with passenger
3. Auto - You rode as a passenger
4. Taxi - Ride alone
5. Taxi - Advanced, shared ride
6. Taxi - Immediate, shared ride

TIME: ____________

(to nearest minute)

These data are CONFIDENTIAL and will be used for travel studies only.

CITY OF XENIA HOME INTERVIEW SURVEY - 1977

Form D

Personal Preference Data
(one form for each person)

To the Interviewer:

IF THE RESPONDENT IS EMPLOYED MORE THAN 30 HOURS/WEEK (FULL TIME) - SEE QUESTION B5 - CHECK "WORK" BOX AT TOP OF FORM D, PRESENT FORM D FOR WORK TRIP AND PRESENT CARD TITLED "WORK TRIP - PART D" TO RESPONDENT.

IF RESPONDENT IS NOT EMPLOYED MORE THAN 30 HOURS/WEEK, CHECK "SHOP" BOX AT TOP OF FORM D, PRESENT FORM D FOR SHOP TRIP AND PRESENT CARD TITLED "SHOPPING TRIP - PART D" TO RESPONDENT.

After the respondent reads the card, the interviewer assists the respondent for the first three or four responses and then goes to Form B with second person. If Form D respondent needs more help, however, interviewer should stay with them. If someone finds Form D impossible to do, don't pressure them and just go on to the second person.

Interviewer should be prepared to spend up to five minutes explaining Form D, how to fill it out, and going through the first response.

WORK TRIP - HOW TO FILL OUT FORM D

We are interested in your opinion of various types of transit services. We have listed on the accompanying form 18 different transit services. We would like you to imagine that you have a job in downtown Xenia, and then tell us how often you would be likely to use each of the alternative services to travel from your home to your job downtown. Please rate each alternative on a scale of "never" to "always" as shown on the accompanying FORM D. For each of these services, we have indicated (1) the type of transit service; (2) the cost of the transit service; (3) how close the service passes to your home; (4) how much longer it would take you to reach your destination downtown using the service than it would if you drove your car. Each of the terms used to describe the service are defined at the bottom of this page. When considering each alternative, you should assume that this service is the only public transit service available to you. If you own a car, or have regular access to one, you should assume that you have a choice of using the car or the transit service described. Remember to respond to all 18 alternatives, please. If you have any questions, please ask the interviewer.

EXPLANATION OF TERMS

1. "Every 15 (or 30) minutes:"

   This refers to a regularly scheduled transit service, like a bus route operating on a fixed route. Assume that you will know the schedule and that the service will operate on time.

2. "Call at least two hours in advance":

   You must call at least two hours before you want the transit service to pick you up, but assume that it will be there when you ask for it.

3. "On Demand":

   The transit service will arrive in 10 or fewer minutes after you telephone for it, just like a taxi.

4. "Cost of service":

   This is the cost of each one-way trip on the transit service.

5. "How close service comes to your residence":

   The transit service will pick you up either 6 blocks from your home, 3 blocks from your home, or else right in front of your home.

6. "How much longer your trip takes by the service":

   This represents how much longer the trip takes by the transit service than if you drove a car.

Form D

Personal Preferences

Household I.D. [ ] [ ] [ ] [ ]

Person Number ______

CHECK ONE: [ ] Work [ ] Shopping

	Type of Transit Service	Cost of Transit Service	How close to Residence	How Much Longer Trip Takes than Automobile	How Frequently You Might Use the Service (Never / Rarely / Half the Time / Usually / Always)
1	Every 30 minutes	Free	In front	No longer	1 2 3 4 5 6 7 8 9 10 11
2	Call at least 2 hours ahead	Free	In front	No longer	1 2 3 4 5 6 7 8 9 10 11
3	Every 15 minutes	50¢	6 blocks	No longer	1 2 3 4 5 6 7 8 9 10 11
4	Call at least 2 hours ahead	$1.00	In front	20 min. longer	1 2 3 4 5 6 7 8 9 10 11
5	Every 15 min.	50¢	In front	10 min. longer	1 2 3 4 5 6 7 8 9 10 11
6	On demand	Free	In front	10 min. longer	1 2 3 4 5 6 7 8 9 10 11
7	Call at least 2 hours ahead	50¢	In front	10 min. longer	1 2 3 4 5 6 7 8 9 10 11
8	Every 30 minutes	$1.00	6 blocks	10 min. longer	1 2 3 4 5 6 7 8 9 10 11
9	On demand	$1.00	In front	10 min. longer	1 2 3 4 5 6 7 8 9 10 11
10	Every 15 minutes	Free	3 blocks	10 min. longer	1 2 3 4 5 6 7 8 9 10 11
11	Call at least 2 hours ahead	Free	In front	20 min. longer	1 2 3 4 5 6 7 8 9 10 11
12	Every 15 minutes	50¢	3 blocks	20 min. longer	1 2 3 4 5 6 7 8 9 10 11
13	Call at least 2 hours ahead	$1.00	In front	No longer	1 2 3 4 5 6 7 8 9 10 11
14	Every 15 minutes	$1.00	3 blocks	No longer	1 2 3 4 5 6 7 8 9 10 11
15	On demand	50¢	In front	No longer	1 2 3 4 5 6 7 8 9 10 11
16	Every 30 minutes	Free	6 blocks	20 min. longer	1 2 3 4 5 6 7 8 9 10 11
17	On demand	50¢	In front	20 min. longer	1 2 3 4 5 6 7 8 9 10 11
18	Every 30 minutes	$1.00	In front	20 min. longer	1 2 3 4 5 6 7 8 9 10 11

APPENDIX D

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

TABLE D.1.6

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

Individual Coefficient Values	[illegible]					
	Income	Household Size	Adult Household Size	Auto Ownership	[illegible]	[illegible]
Overall Test on Regression Coefficients						
[illegible]			*			
[illegible]	***					
[illegible]			*			
[illegible]						
[illegible]						
[illegible]	*			***		
[illegible]				*		
[illegible]			*			
[illegible]						
Intercept (Overall Mean)	—		**			
Overall Test on Weight Coefficients				***		
[illegible]			*			
[illegible]				*		
[illegible]						
[illegible]			*	**		

[illegible] percent significance level
[illegible] percent significance level
[illegible] percent significance level

TABLE D.1.a

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

Individual Coefficient Values	Interpersonal Measures					
	Trip Purpose	Previous Transit Use	Sex	Age	Possession of License	Education
Overall Test on Regression Coefficients			***			
Type of Service	*					
Bus Headway					**	
Taxi Headway	**		***			
Fare (Cost)						
Walk (Blocks)			*			
Time Diff.		*				
Fare Squared						
Walk Squared					***	
Time Squared			**			
Intercept (Grand Mean)						
Overall Test on Weight Coefficients			***			
Mode/Headway			***			
Fare (Cost)				**		
Walk (Blocks)						
Time Diff.						

*90 percent significance level
**95 percent significance level
***99 percent significance level

TABLE D.1.b

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

Individual Coefficient Values	Interpersonal Measures: Income	Household Size	Adult Household Size	Auto Ownership	Purpose & Previous Use	Purpose & Sex
Overall Test on Regression Coefficients						
Type of Service			*			
Bus Headway	***					
Taxi Headway			*			
Fare (Cost)						
Walk (Blocks)						
Time Diff.	*			***		
Fare Squared				*		
Walk Squared			*			
Time Squared						
Intercept (Grand Mean)			**			
Overall Test on Weight Coefficients				***		
Mode/Headway			*			
Fare (Cost)				*		
Walk (Blocks)						
Time Diff.			*	***		

*90 percent significance level
**95 percent significance level
***99 percent significance level

TABLE D.1.c

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

Individual Coefficient Values	Interpersonal Measures					
	Purpose and Age	Purpose and License	Purpose and Education	Purpose and Income	Purpose and Household Size	Purpose and Adult Household Size
Overall Test on Regression Coefficients						
Type of Service						
Bus Headway		*				
Taxi Headway	***					
Fare (Cost)						
Walk (Blocks)						
Time Diff.						
Fare Squared					***	
Walk Squared						
Time Squared				*		
Intercept (Grand Mean)						
Overall Test on Weight Coefficients						
Mode/Headway	*					
Fare (Cost)	*					*
Walk (Blocks)						
Time Diff.						

*90 percent significance level
**95 percent significance level
***99 percent significance level

TABLE D.1.d

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

Individual Coefficient Values	Interpersonal Measures					
	Purpose and Auto Ownership	Previous Use and Sex	Previous Use and Age	Previous Use and License	Previous Use and Education	Previous Use and Income
Overall Test on Regression Coefficients						
Type of Service						
Bus Headway			**			
Taxi Headway	***					
Fare (Cost)						
Walk (Blocks)						
Time Diff.						*
Fare Squared			**			**
Walk Squared			*			
Time Squared						
Intercept (Grand Mean)						
Overall Test on Weight Coefficients						
Mode/Headway						
Fare (Cost)	**			**		
Walk (Blocks)						
Time Diff.						

*90 percent significance level
**95 percent significance level
***99 percent significance level

TABLE D.1.e

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

Individual Coefficient Values	Interpersonal Measures					
	Previous Use & Household Size	Previous Use & Adult Household Size	Previous Use & Auto Ownership	Sex & Age	Sex & License	Sex & Education
Overall Test on Regression Coefficients		**	**	*		
Type of Service						
Bus Headway			***			
Taxi Headway		*		***	**	
Fare (Cost)		**	*	***		
Walk (Blocks)						
Time Diff.			***			
Fare Squared			***			*
Walk Squared						
Time Squared						
Intercept (Grand Mean)	*		*			
Overall Test on Weight Coefficients	**			***		
Mode/Headway				**		
Fare (Cost)	**	*		**		
Walk (Blocks)	*					
Time Diff.				***		

*90 percent significance level
**95 percent significance level
***99 percent significance level

TABLE D.1.f

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

	Interpersonal Measures					
Individual Coefficient Values	Sex & Income	Sex & Household Size	Sex & Adult Household Size	Sex & Auto Ownership	Age & License	Age & Education
Overall Test on Regression Coefficients				**		**
Type of Service						
Bus Headway		**			***	***
Taxi Headway				***		*
Fare (Cost)						
Walk (Blocks)				**	*	
Time Diff.						
Fare Squared		**			*	
Walk Squared		*		**		
Time Squared						
Intercept (Grand Mean)					*	
Overall Test on Weight Coefficients	*			*		
Mode/Headway				*		
Fare (Cost)						
Walk (Blocks)						
Time Diff.	**			***		

*90 percent significance level
**95 percent significance level
***99 percent significance level

TABLE D.1.g

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

Individual Coefficient Values	Interpersonal Measures					
	Age & Income	Age & Household Size	Age & Adult Household Size	Age & Auto Ownership	License & Education	License & Income
Overall Test on Regression Coefficients						
Type of Service				***		
Bus Headway	*				**	
Taxi Headway	**	**	**			
Fare (Cost)			**			
Walk (Blocks)	*					
Time Diff.						
Fare Squared				*	**	
Walk Squared	*			*	**	
Time Squared				**		
Intercept (Grand Mean)	*					
Overall Test on Weight Coefficients				**		
Mode/Headway	**				**	
Fare (Cost)	**			**		
Walk (Blocks)						
Time Diff.				*		

*90 percent significance level
**95 percent significance level
***99 percent significance level

TABLE D.1.h

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

Individual Coefficient Values	Interpersonal Measures					
	License & Household Size	License & Adult Household Size	License & Auto Ownership	License & Education	License & Income	License & Household Size
Overall Test on Regression Coefficients						
Type of Service						
Bus Headway					**	
Taxi Headway		*				
Fare (Cost)			**			
Walk (Blocks)	**		*			
Time Diff.	**		**			**
Fare Squared					**	**
Walk Squared					**	
Time Squared	*	*				*
Intercept (Grand Mean)	*					*
Overall Test on Weight Coefficients						
Mode/Headway		*		**		*
Fare (Cost)						
Walk (Blocks)						
Time Diff.			**			

*90 percent significance level
**95 percent significance level
***99 percent significance level

TABLE D.1.i

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

	Interpersonal Measures					
Individual Coefficient Values	& Adult Househdld Size	License & Auto Ownership	Education & Income	Education & Household Size	Education & & Auto Ownership	Income & Household Size
Overall Test on Regression Coefficients						
Type of Service						
Bus Headway						
Taxi Headway	*				*	
Fare (Cost)		**				
Walk (Blocks)		*				
Time Diff.		**				
Fare Squared						
Walk Squared			*			
Time Squared	*					*
Intercept (Grand Mean)						*
Overall Test on Weight Coefficients						
Mode/Headway	*					
Fare (Cost)				*		
Walk (Blocks)						
Time Diff.		**				

*90 percent significance level
**95 percent significance level
***99 percent significance level

TABLE D.1.j

Results of Multiple Analyses of Variance for Individual Regression Coefficients and Weights

Individual Coefficient Values	Interpersonal Measures					
	Income & Adult Household Size	Income & Auto Ownership	Household Size & Adult Size	Household Size & Auto Ownership	Adult Household Size & Auto Ownership	Overall Test for Regression Coefficients
Overall Test on Regression Coefficients		***				
Type of Service			**			
Bus Headway			*			
Taxi Headway			**		*	*
Fare (Cost)			**			
Walk (Blocks)		*	**	*		
Time Diff.				*		*
Fare Squared	*		*		*	
Walk Squared		**	***			
Time Squared						
Intercept (Grand Mean)			***			**
Overall Test on Weight Coefficients		*	**			
Mode/Headway		**	*			
Fare (Cost)						
Walk (Blocks)						**
Time Diff.	*		***			

*90 percent significance level
**95 percent significance level
***99 percent significance level

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